Chapter 3. Statewide Overview

In the development of the Virginia CWCS, we intended to present information about species, their essential habitats, threats, conservation actions, and survey/research/monitoring needs at the ecoregional level to maximize opportunities to effect on-the-ground conservation efforts. During our evaluation and assessment of the status of Virginia's wildlife and habitat resources, it became clear that some of the results were applicable statewide. We also determined that some of our analyses could not be applied at the ecoregional level, since the information is simply unavailable at that scale.

This statewide overview about the species of greatest conservation need, habitats, threats, monitoring, conservation actions, and public input provides a context in which the more specific outcomes identified in the ecoregional chapters may be considered.

3.1. Species of Greatest Conservation Need

3.1.1. Summary by Taxonomic Group and Tier

The draft list of species of conservation need, which included all species found on any conservation list, contained 1433 species (see Section 2.3 for details on the selection process). After review by the TACs, this list was reduced to 925 species (Table 3.1). "Other terrestrial invertebrates" (millipeds, spiders, terrestrial snails, etc.) is the largest tiered group, with over 21% of the total species count. Terrestrial insects account for nearly 16%, and aquatic insects have slightly more, so that insects in general account for 31.4% of all species of greatest conservation need in Virginia. Invertebrates together account for 70% of tiered species, leaving the more visible vertebrates to make up the other 30%.

Fishes and birds have the most inclusion of the vertebrates, with 35% each (10.5% each overall). The other 30% of the vertebrates is split relatively evenly: amphibians (12%), reptiles (10%), and mammals (9%).

In terms of tiers, 10% of all species of greatest conservation need are in Tier I, 27% are in Tier II, 20% are in Tier III, and 43% are in Tier IV (Table 3.2).

Table 3.1. The number of species in each taxonomic group that was first identified as possible species of conservation need ("Number in Draft List") and the number that was selected by the TACS.

Taxonomic Group	Number in Draft List	Number in Final List [1]
Fishes	99	97
Amphibians	32	32
Reptiles	28	28
Birds [2]	218	96
Mammals	37	24
Terrestrial insects	432	144
Other terrestrial invertebrates	217	196
Aquatic mollusks [3]	91	89
Aquatic crustaceans [4]	78	61
Aquatic insects	189	146
Other aquatic invertebrates	12	12

[1] This final number may reflect additions to or removals from the draft list (or both).
[2] Bird TAC used a Partners In Flight-like approach, incorporating trend and range data into the modification of the bird tiers, rather than relying solely on the professional judgment that other TACs did (since this kind of detailed biological information is not available for other taxonomic groups).
[3] Terrestrial mollusks are included in the "Other terrestrial invertebrates" group.
[4] Terrestrial crustaceans are included in the "Other terrestrial invertebrates" group.

Table 3.2. Summary of tiered species by taxonomic group.

Taxonomic Group	**Tier I**	**Tier II**	**Tier III**	**Tier IV**	**Total**
Fishes	11	15	18	53	97
Amphibians	1	12	8	11	32
Reptiles	5	4	6	13	28
Birds	15	14	12	55	96
Mammals	5	6	3	10	24
Terrestrial insects	7	53	28	56	144
Other terrestrial invertebrates	6	77	41	72	196
Aquatic mollusks	24	20	16	29	89
Aquatic crustaceans	9	24	13	15	61
Aquatic insects	5	22	39	80	146
Other aquatic invertebrates	5	4	1	2	12
Total	93	251	185	396	**925**

3.1.2. Summary of Listed Species (Endangered and/or Threatened)

Forty-four species of greatest conservation need are listed as Federally threatened or endangered, and 99 are State threatened or endangered (Table 3.3). Overall, 105 unique tiered species (11.4%) are listed as threatened or endangered at the State and/or Federal level. When considering these numbers, it is important to remember that State and Federal statuses are not mutually exclusive; many of these 105 species have both a State and Federal status. Of all tiered species, 3.8% are Federal endangered, 1% are Federal threatened, 6.6% are State endangered, 4.1% are State threatened, 35.7% are Federal species of concern, and 6.6% are State special concern. Virginia or USFWS have identified 46.8% of all species of greatest conservation need as having one of these statuses overall.

An additional 61 species have been designated as State special concern, while 330 have been given the designation of "species of concern" by the USFWS Virginia Field Office (Table 3.3). These are not legal statuses in the way that "endangered" or "threatened" are. These statuses may reflect uncertainty about a species' status, or that the species is susceptible to decline in Virginia: it may be a habitat specialist, use a specific habitat that is particularly threatened, or face otherwise imminent threats, regardless of its current population levels. Again, as mentioned above regarding State and Federal endangered and threatened, these categories are not mutually exclusive, and a given species may be counted in one or both.

3.2. Statewide Habitat: Status and Trends

3.2.1. Terrestrial Spatial Variables

Statewide terrestrial habitat variables, including land cover, place, and various topographic factors, have been compiled for use in this strategy and beyond. These variables have been used to create essential habitat data layers for Tier I terrestrial species. In the future, these variables can be combined in various ways to define specific habitat types (e.g., high elevation cove forest). No attempt to report or display every combination of the variables has been made. A CD-ROM containing these datasets as ArcInfo® GRIDs, along with metadata records, are included with this strategy. A brief discussion of the relevant statewide results of these variables is presented below.

3.2.1.1 Land Cover

According to USGS (1992), over 60% of Virginia is forested (Table 3.4). "Agriculture/open" is the second most abundant land cover type at just under 24%. "Open water," including waters of the Chesapeake Bay, is third. Because of the methods used to create this layer from satellite imagery, "developed" areas may be underreported at slightly over 3% of the land area.

Table 3.3. Numbers of species of greatest conservation need that are listed as threatened, endangered, or of special conservation concern by Virginia or USFWS.

Taxonomic Group	Federal Endangered	Federal Threatened	State Endangered	State Threatened	Federal Species of Concern	State Special Concern	Total [1]
Fishes	3	3	7	13	28	17	50
Amphibians	1	0	2	2	4	9	13
Reptiles	0	2	3	3	2	1	9
Birds	2	2	4	8	5	16	30
Mammals	5	0	9	1	6	1	14
Terrestrial insects	2	1	0	0	86	0	88
Other terrestrial invertebrates	1	0	4	3	106	1	104
Aquatic mollusks	19	0	31	7	26	6	53
Aquatic crustaceans	1	1	1	1	39	10	43
Aquatic insects	0	0	0	0	21	0	21
Other aquatic invertebrates	0	0	0	0	7	0	8
Total	35	9	61	38	330	61	**433**

[1] This column is the total number of species in that group that have one or more of these statuses. Since Federal and State statuses are not mutually exclusive (that is, a species can and often does have both a Federal and a State status), this total is usually less than the sum of a row. The total in the bottom-right corner is the total number of species (the column sum, not the row sum).

Table 3.4. Land cover of Virginia in approximate square kilometers and percentage (USGS 1992).

Land Cover Type	Square Kilometers	Percentage
Open Water	8650	7.75
Developed	3750	3.38
Barren	200	0.20
Forest	68350	61.31
Agriculture/Open	26350	23.65
Wetland	4150	3.71

The eastern portion of Virginia appears at first glance to be mostly forested (Figure 3.1). However, much of the forest area is fragmented into small patches by agriculture/open or developed areas. Most of the higher elevation and steeper sloped areas of western Virginia are forested. However, the more fertile valleys and lower lands in the west are primarily agriculture/open. The vast majority of wetlands occur in the eastern third of the Commonwealth. The largest developed areas occur in the crescent from northern Virginia (outside of Washington, D.C.), south to Richmond, and then southeast to Norfolk and Virginia Beach.

3.2.1.2. Place

A majority of Virginia (54%, Table 3.5) is classified as submontane. Montane accounts for over one-third of the area of the Commonwealth. High elevation is by far the rarest place category at less than 1%. However, these areas represent critical habitat for many wildlife species. The spatial distribution of Place categories can be seen in Figure 2.3.

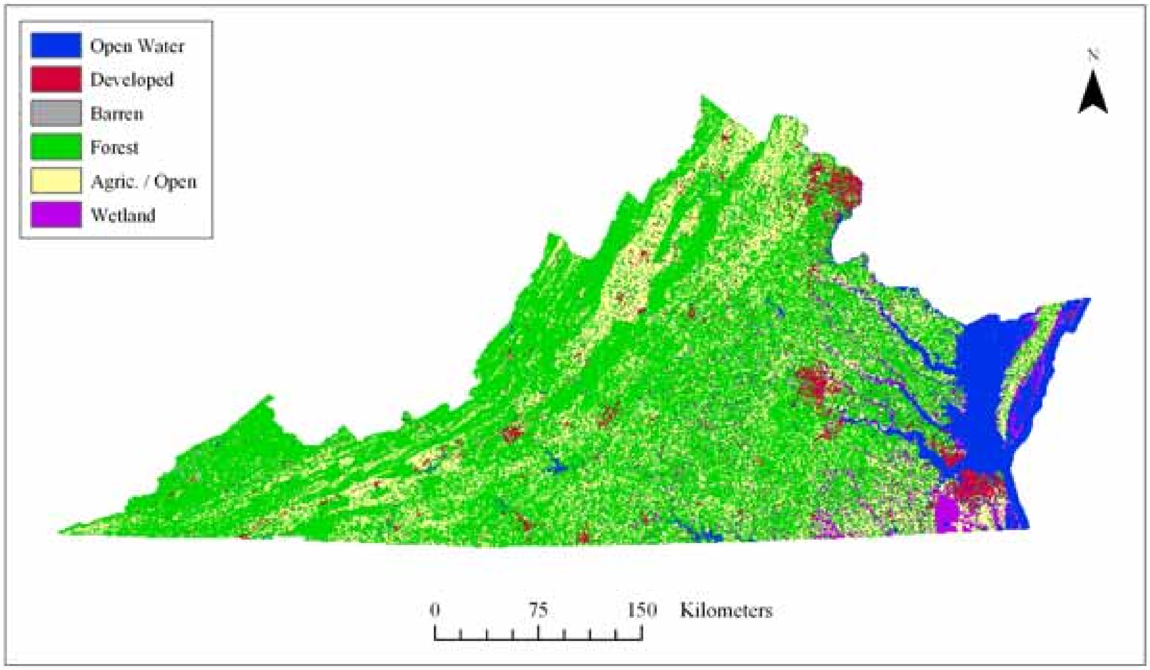

Figure 3.1. Land cover of Virginia (USGS 1992).

Table 3.5. Place categories in Virginia in approximate square kilometers and percentage.

Place Categories	Square Kilometers	Percentage
Submontane	61000	53.96
Montane	41400	36.61
High Elevation	750	0.67
Estuarine/Marine	9900	8.75

3.2.1.3. Topographic Habitat Variables

Several terrestrial habitat variables were derived from digital elevation models. These topographic habitat variables include relative phenological index (RPI), slope, aspect, topographic moisture index (TMI), and landform index. Because these factors influence habitat on a very fine scale, statewide results for them are not presented in the CWCS (with the exception of RPI, below).

Relative phenological index shows areas of relatively similar temperature, based on location and elevation (Figure 3.2). It measures the delay in phenological event in days, starting in far southeastern Virginia. Since other topographic factors, such as aspect, slope, and landform, are important in determining temperature regime at specific sites, RPI is more appropriate for statewide and regional use, rather than fine scale modeling. When examining RPI statewide, much of the Coastal Plain and Piedmont are similar, due to the lack of significant elevation change. More dramatic phenologic change occurs in the mountains of the Blue Ridge, Ridge and Valley, and Cumberland Mountain ecoregions. Rare northern relict vegetation communities (e.g., spruce-fir forests and mountain balds) and wildlife species (e.g., snowshoe hare *Lepus americanus*) are identified by high RPI values in the Blue Ridge and Ridge and Valley.

3.2.2. Terrestrial GAP Analysis

Gap analysis attempts to find the holes or "gaps" in a reserve network by identifying areas of high species richness and assessing their degree of "protectedness." The goal of Gap analysis is to keep common species

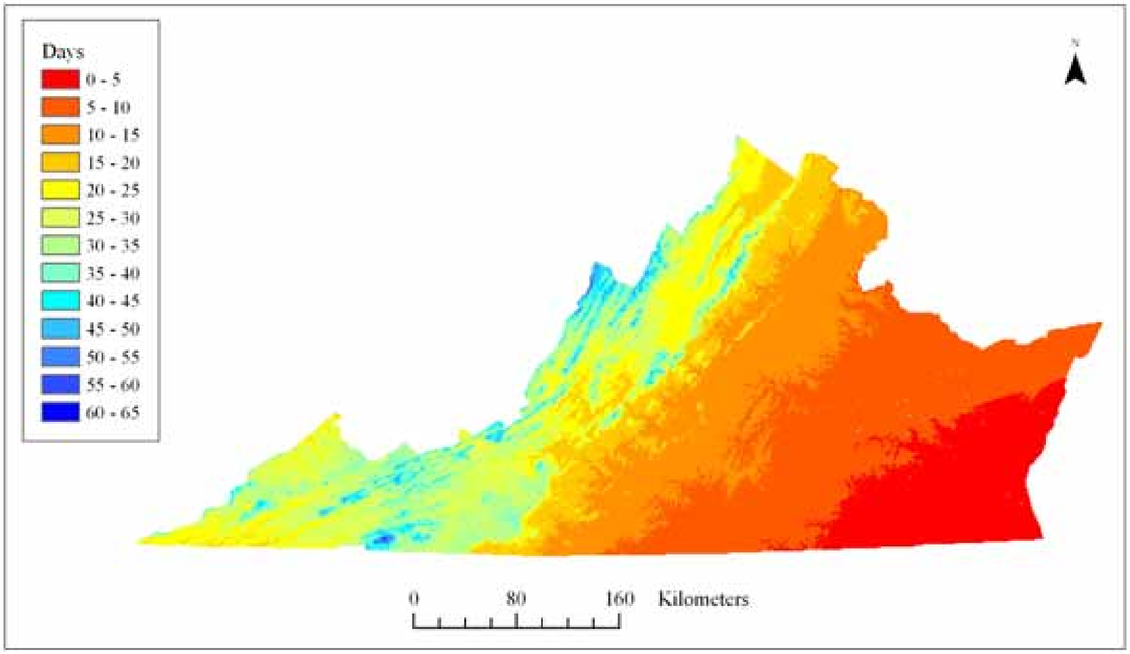

Figure 3.2. Relative Phenological Index, showing the delay in phenologic events in days as a function of geography and elevation.

common by identifying those wildlife species that are not adequately represented in existing conservation lands (USGS 2005b). The Virginia Gap Analysis Project (VA-GAP) was a cooperative effort between USGS, CMI, DGIF, and other state, federal, and private natural resources groups in Virginia. The major objectives of the project were to: (1) produce GIS databases describing the actual land cover (vegetation types), predicted distributions of terrestrial vertebrates, predicted species richness, and actual land ownership; (2) identify land cover types and terrestrial vertebrate species that currently are not represented or are underrepresented in areas managed for long-term maintenance of biodiversity (i.e. "gaps" in protection); and (3) facilitate cooperative development and use of information so that institutions, agencies, and private land owners may be more effective stewards of Virginia's natural resources (Waldon et al. 2001).

The final VA-GAP report (Waldon et al. 2001) was submitted to USGS in 2001. Since that time, wildlife species range information has been reviewed and revised by experts across Virginia. These updates have been incorporated into VAFWIS and VA-GAP predicted potential species distributions (DGIF 2004). Changes in range information resulted in a few deletions from the list of VA-GAP terrestrial vertebrate species, since some species were considered extirpated (Morton et al. 2004).

Stewardship information has also been updated since the VA-GAP report. The Conservation Lands Database was created by DCR (2003). This database is a much broader and less selective compilation of protected lands than the VA-GAP stewardship layer. By comparison, VA-GAP Stewardship (gap status 1, 2, and 3) contains 10,348km^2 (10.1% of Virginia), while the Conservation Lands Database contains 12,913 km^2 (12.6% of Virginia). By comparing the Conservation Lands Database to the predicted distributions of individual species, it was possible to identify species that are relatively underprotected in the current reserve network. Species with less than 10% of their predicted potential distribution in a Conservation Land were labeled "underprotected". Of the 568 terrestrial vertebrate species included in VA-GAP, 148 had potential habitat area below this 10% threshold. Because of the relatively low proportion of their habitat within conservation lands, it is assumed that these are these are the most vulnerable species.

Because of the large numbers of species analyzed during the VA-GAP process, the predicted distributions of individual species were based on simplistic habitat relationships. Individual predicted species distributions are not appropriate for this conservation strategy due to the simple and broad nature of these models. However, the derived species richness maps provide important information on the statewide patterns of species diversity. Overall, the highest terrestrial vertebrate species richness occurs in far southeastern Virginia (Figure 3.3), particularly wetland habitats. Forested areas in the mountains of western Virginia are also species rich.

Wetlands in southeastern Virginia support the highest number of amphibian species (Figure 3.4). Wetlands and open/agricultural fields in Washington and Smyth counties of southwestern Virginia are a second area of high amphibian species richness.

Birds are by far the most numerous taxonomic group considered in VA-GAP, so their richness patterns (Figure 3.5) drive the overall richness map (Figure 3.3). Southeastern Virginia and the Eastern Shore support the largest number of bird species.

Forested areas in the mountains of western Virginia contain the highest number of mammal species (Figure 3.6).

As with most taxonomic groups, the highest number of reptile species occurs in far southeastern Virginia (Figure 3.7). The Eastern Shore and western Virginia contain fewer species of reptiles.

"Underprotected species richness" depicts areas that contain a high number of relatively underprotected species (Figure 3.8). This richness layer identifies conservation targets that would benefit terrestrial species richness the most. These are the "gaps" in the conservation reserve network. Considering that most of the conservation lands are in western Virginia (e.g., George Washington and Jefferson National Forests) and the highest species richness is in the southeast, it is not surprising that Figure 3.8 shows that the greatest number of conservation opportunities exist in southeastern Virginia. However, other areas that are relatively unprotected include Loudoun and Albemarle counties in the Piedmont.

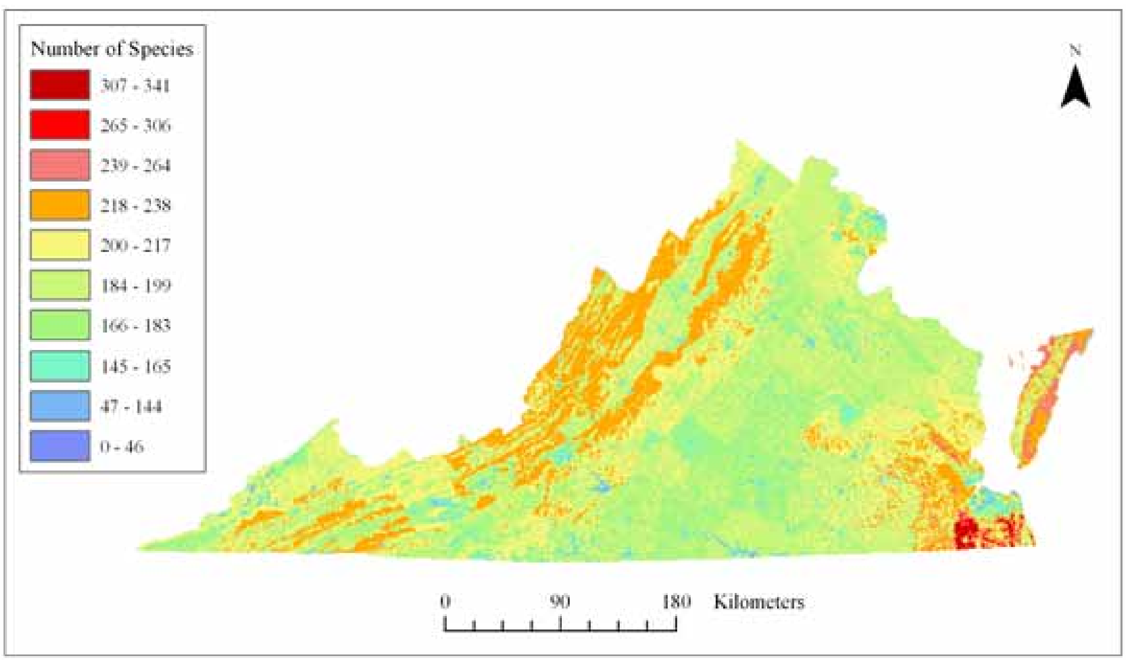

Figure 3.3. VA-GAP overall species richness.

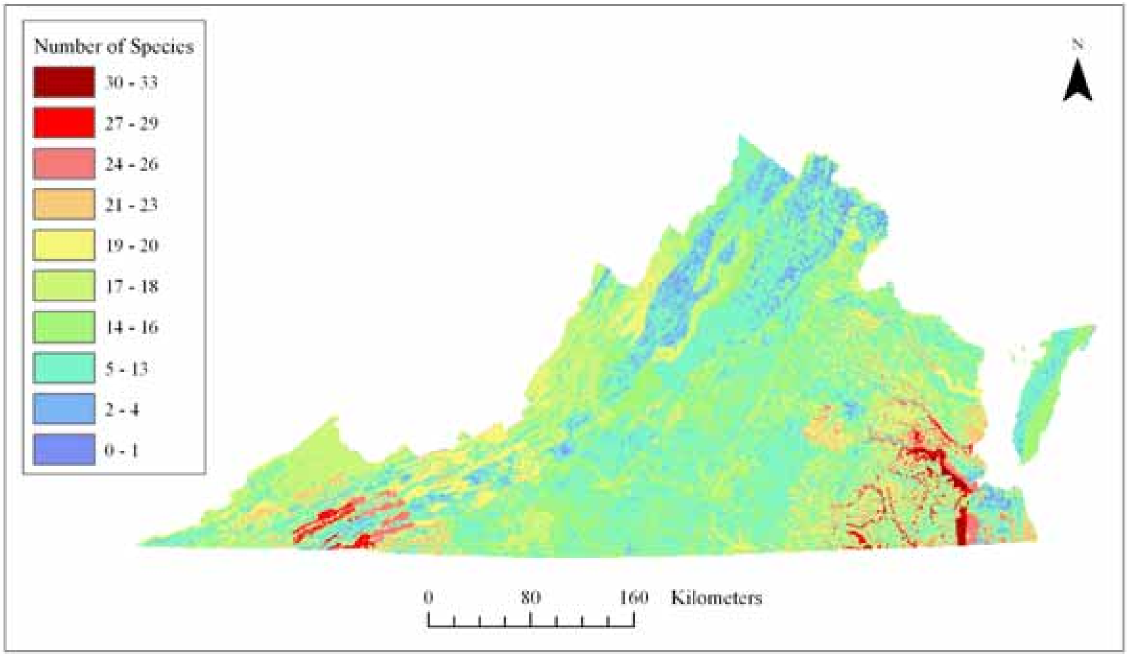

Figure 3.4. VA-GAP amphibian species richness.

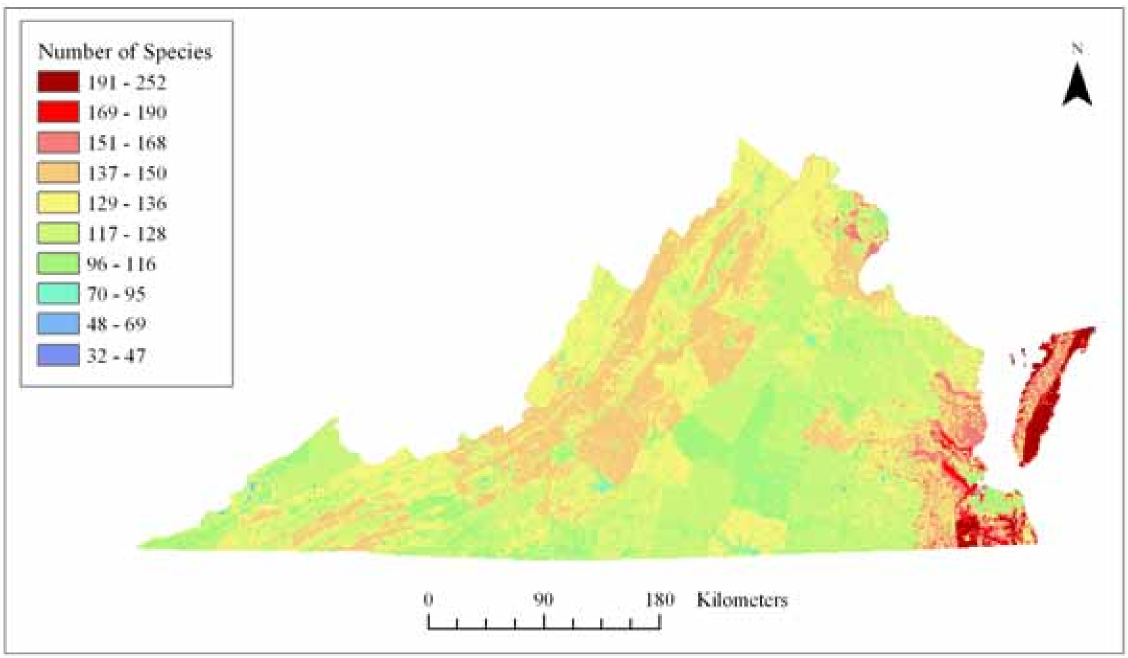

Figure 3.5. VA-GAP bird species richness.

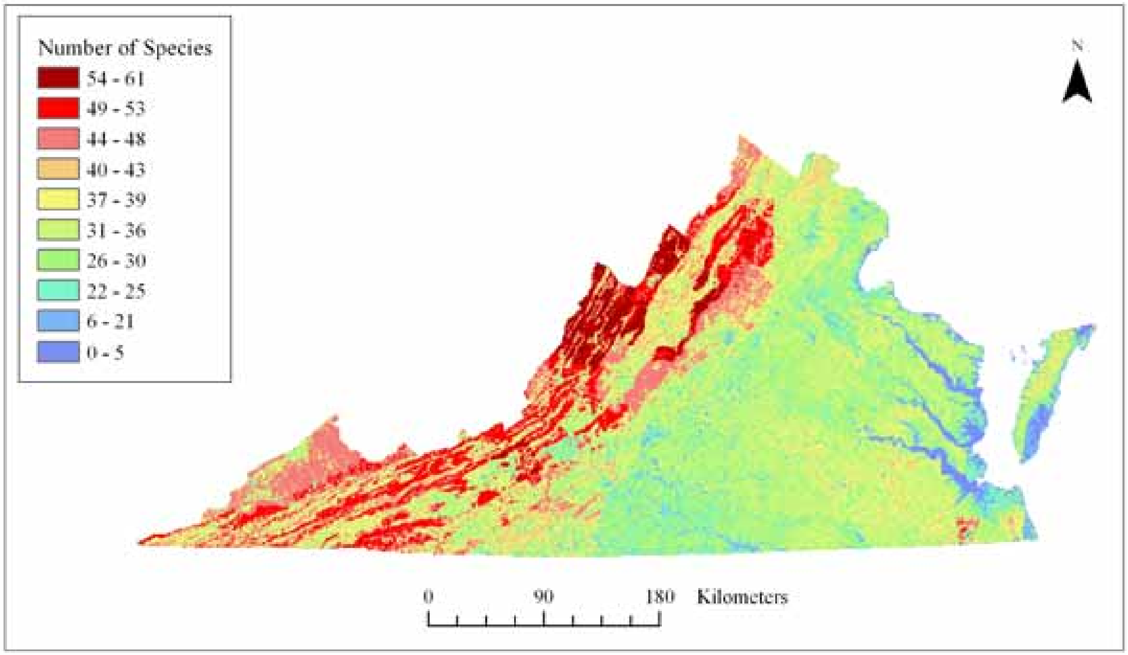

Figure 3.6. VA-GAP mammal species richness.

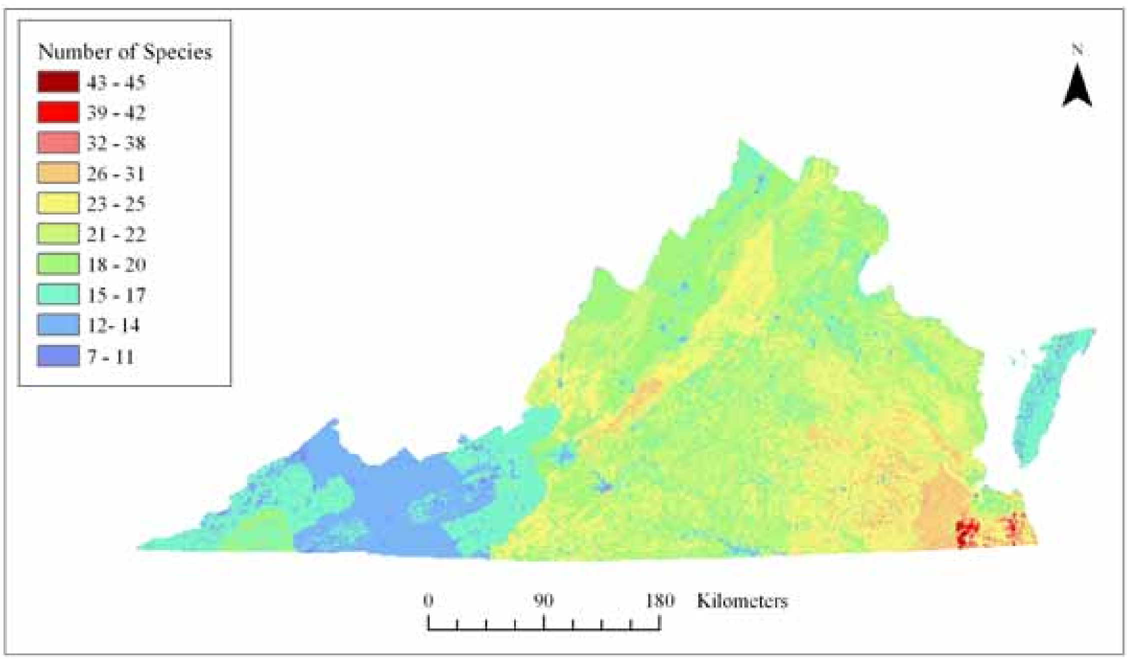

Figure 3.7. VA-GAP reptile species richness.

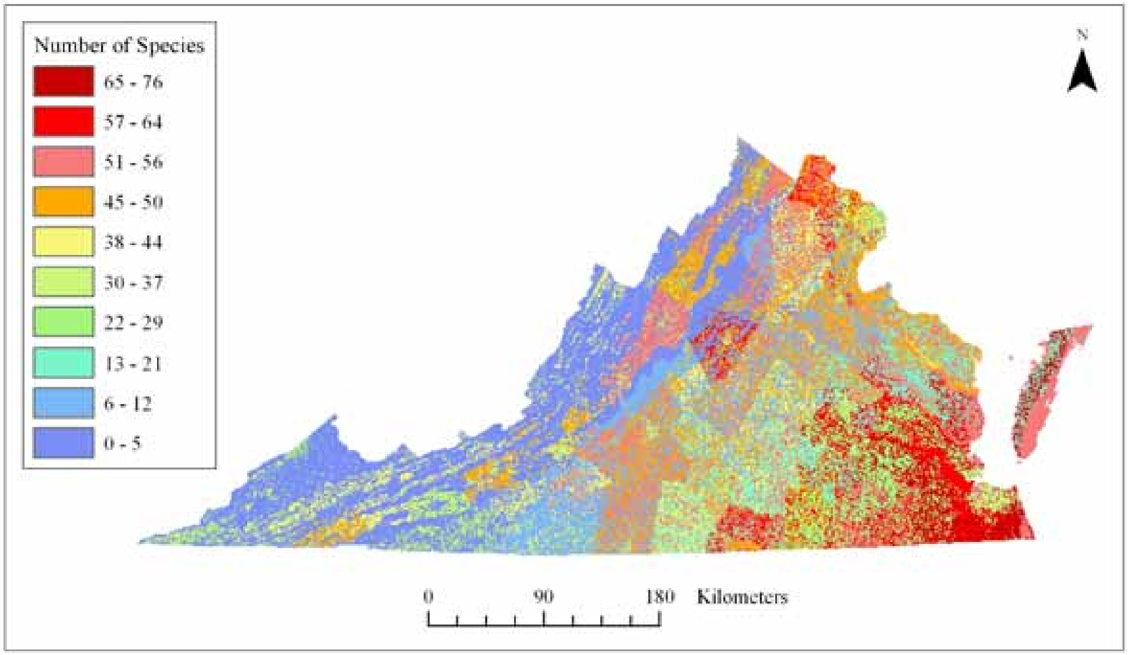

Figure 3.8. VA-GAP underprotected species richness. Areas with the highest number of species that have underprotected habitat appear as red.

3.2.3. Statewide Terrestrial Habitat Status and Trends

3.2.3.1. Statewide Forest

Statewide Forest Status

According to the 2001 FIA (USFS 2001), Virginia has 6.4 million ha of forestland, of which 1.4 million ha is conifer, 4.2 million ha is deciduous, and 0.8 million ha is mixed forest. An additional 4.7 million ha is unforested land. Of this total forest area in Virginia, 1.0 million ha are in public ownership (0.9 million ha federal, 0.1 million ha state, 40,000ha county/municipal), and 5.5 million ha are in private ownership (0.6 million ha forest industry, 4.8 million ha non-industrial private) (Smith et al. 2005).

Since approximately 85% of Virginia's forestland is in private ownership, it is clear that the private landowner is critical to conservation efforts. The average non-industrial private forest holding in Virginia is 29 acres (11.7ha) (Birch et al. 1998). This small patch size corresponds with a decrease in privately-held forest tracts over 100 acres (40.5ha), illustrating the ongoing fragmentation of parcel ownership (Birch et al. 1998). The majority of landowners (66%) own only one tract; this accounts for 36% of forestland in Virginia (Birch et al. 1998). While almost 46% of owners own forest simply because it is part of their farm or residence, this accounts for less than 10% of the total forestland and is made up mainly of small tracts (Birch et al. 1998). Recreation and esthetic enjoyment are the reasons given by 24% of owners, accounting for 18% of private forest holdings.

While only 10% of private forest owners list timber production as their primary purpose for owning forestland, this accounts for 18% of the privately-held forestlands (Birch et al. 1998). Those landowners intending to harvest within 10 years (37% of owners) control 53% of Virginia's forest; 44% of owners never intend to harvest, but these owners only hold 13% of the privately-held forestland. Approximately 17% of private forestland owners have a written management plan; these owners control 33% of the private forest (Birch et al. 1998).

Of Virginia's deciduous forest complex, 1.1 million acres (445,000ha) are affected by oak decline, a disease complex including the fungus *Armillaria mellea* and the two-lined chestnut borer *Agrilus bilineatus* (Wargo et al. 1983). This syndrome attacks trees in a weakened state from drought or insect-related defoliation, causing dieback of the branches (Wargo et al. 1983). The amount of affected area in Virginia was stable from 1984-1997 (Oak et al. 2004). Oak decline was recorded in almost 20% of host type FIA plots in both the 1984-1989 and 1991-1997 surveys (Oak et al. 2004). While mortality usually takes years to decades to occur (Oak et al. 2004), this disease complex is a serious threat to the deciduous forests of Virginia.

Statewide Forest Trends

In 1630, Virginia had an estimated 24.5 million acres (9.9 million ha) of forest (Smith et al. 2005). Over 10 million acres (4 million ha) of this area were cleared by 1907; between 1907 and 1963, forest increased from 14 million acres (5.7 million ha) to 16.4 million acres (6.6 million ha) (Smith et al. 2005). Forestland in Virginia has held steady since then, dropping slightly to 16.1 million acres (6.5 million ha) in 2002 (Smith et al. 2005), an annual decline of only 0.013%.

The 2001 FIA (USFS 2001) reports a net loss of 20,000 acres (8,100ha) of forest per year from 1992 to 2001 (Scrivani and Pemberton 2003). There were slight gains overall in the Coastal Plain and the southern mountains, small losses in the northern mountains and southern Piedmont, and considerable losses (71,000ha) in the northern Piedmont (Scrivani and Pemberton 2003). These management regions do not conform to the ecoregions used in the preparation of the CWCS.

Scrivani and Pemberton (2003) reported trends in harvest practices. Partial harvest increased 154% over the 1992-2001 survey period, while clearcuts decreased 16%. In addition, commercial thinning increased 35%. Natural regeneration increased by 7%, while planting/artificial regeneration decreased by 15%.

During the 1992-2001 FIA cycles, upland deciduous forest decreased 2.1%, lowland deciduous increased 1.8%, mixed oak-pine decreased 1.2%, natural coniferous decreased 18%, and pine plantation increased 25% (Scrivani and Pemberton 2003).

As mentioned above, forestland in private ownership is tending to become fragmented into smaller and smaller ownership parcels (Birch et al. 1998). This may be problematic insofar as smaller patches are more difficult to manage effectively as habitat for wildlife, and these smaller forest tracts may be more vulnerable to sale and development.

3.2.3.2. Statewide Open Habitat

Open Habitat Status

The 1997 NRI reports that 73% of Virginia's surface area is non-Federal rural land, with the remainder being made up of Federal land (10%), developed land (10%), and water (7%) (USDA 2000). Of this 73%, 2.9 million acres (1.18 million ha) is cropland, 3 million acres (1.21 million ha) is pastureland, and 70,000 acres (28,600ha) is enrolled in CRP (USDA 2000).

Open Habitat Trends

Between 1982 and 1997, Virginia experienced a net loss of 0.48 million acres (0.19 million ha) of cropland to development, pastureland, forest regeneration, and other uses (USDA 2000). However, of this loss only about 36% was permanent loss to urban development, while the remaining 63% is capable of returning to cropland in the future (USDA 2000). During the same period, a loss of 0.25 million acres (103,000ha) of pastureland occurred, 50% of which was permanently lost to development (USDA 2000). Overall, during the 1982-1997 period, 0.77 million acres (0.31 million ha), including all landcover types, were developed in Virginia.

3.2.3.3. Statewide Barren and Developed Areas

Barren Habitat Status and Trends

Little information is available for barren habitats in Virginia. Quarries, cliff faces, sand pits, rocky balds, and other widely-dispersed barren habitats are not frequently (if ever) monitored, so current status and trends are difficult to determine. Where possible, some of this information may be found in the Tier I species accounts in the ecoregional chapters (4-9) for those species that use these habitats (e.g., peregrine falcon *Falco peregrinus* in Chapter 7, Northern Ridge and Valley).

Specific information about the protectedness of beach habitats may be found in specific Tier I species accounts in Chapter 4 (the Coastal Plain). Overall, Virginia has 9,348ha of coastal barren area, most of which is beach (although it is impossible to differentiate beach from other barren areas precisely due to similarities of appearance at this scale) (DCR 2003). Of this, 4,247ha is protected in Conservation Lands (DCR 2003). Most of the beach on barrier islands is owned by TNC or government agencies and are reasonably protected from development. Also, a large percentage of beach habitat in southeastern Virginia is protected by government ownership (e.g., Back Bay NWR and First Landing State Park). Many of the smaller beach areas on the bayside of the Eastern Shore and on the Western Shore of the Chesapeake Bay are not protected.

Developed Area Status

Approximately 2.6 million acres (1.0 million ha, about 10%) of Virginia's land area is covered with developed areas (USDA 2000). This includes all developed areas, from rural transportation infrastructure to inner city; as such, this is a very broad land cover class, much of which is not useful as wildlife habitat. However, some species of greatest conservation need do occur in developed residential areas; see each ecoregional chapter (Chapters 4-9) for lists of these species.

Developed Area Trends

The 1997 NRI summary (USDA 2000) reports that, for the survey period 1982-1987, developed areas increased by 17%. This dropped to an increase of 12% during 1987-1992, but rebounded to 19% between 1992 and 1997 (USDA 2000). See Section 3.3.2 for spatial trends in human population and development.

3.2.3.4. Statewide Wetland Habitat

Status of Wetlands

About 4% of Virginia's land cover is wetland (Dahl 1990). Of this area, about 72% is in the Coastal Plain, 22% in the Piedmont, with most of the rest within the two Cumberland Mountain ecoregions (DEQ and DCR 2004). Most of Virginia's wetlands are palustrine, either forested, emergent, or scrub-scrub; these types account for nearly 1.1 million acres (0.45 million ha) of wetlands. Estuarine, lacustrine, and riverine wetlands together account for about 0.19 million acres (76,900ha), and isolated wetlands add another 0.2 – 0.4 million acres (80,000 – 160,00ha) (Hershner et al. 2000).

Virginia contains 40% of the wetlands in the Chesapeake Bay watershed (271,350ha, Tiner N.d.). As such, Virginia's wetlands have a large effect on the Bay. Within the Bay watershed, the largest cause of palustrine forest destruction is creation of reservoirs (45% of loss), followed by urban development (15%), pond construction (14%), and agriculture (14%). For palustrine scrub-shrub wetlands, 65% of all loss is attributable to reservoir creation, followed by pond construction (18%) and agriculture (16%). Finally, the primary cause of palustrine emergent wetland destruction in the Bay watershed is agriculture (37%), followed by pond construction (27%). Of seven areas identified by Tiner (N.d.) as hot spots of wetland loss in the Bay watershed, four are in Virginia: southeastern Virginia, the Piedmont, the upper Coastal Plain, and western Virginia (including all of the mountains). This essentially encompasses all of Virginia's portion of the Bay watershed.

Wetland Trends

In the period between 1780 and 1980, Virginia lost about 42% of its wetlands (Dahl 1990). Most of these losses were of palustrine forested wetlands, and most (80%) occurred in the Coastal Plain (DEQ and DCR 2004).

The Chesapeake Bay Program (2004) reports that, between 2001-2003, Virginia had restored 13% (794 acres, or 321ha) of its 6,000-acre (2,428ha) goal under the Chesapeake Bay Agreement. "Restoration," as used here, includes "restoration, enhancement, and creation of tidal and non-tidal wetlands in the Wetlands Restoration Program." However, it is noted that the data on which this restoration estimate was based are not comprehensive and do not include wetlands restoration under other programs, such as CREP or other Farm Bill programs (CBP 2004).

In recent times, wetland losses are surprisingly tricky to quantify. An online data query tool to support assessments of wetlands loss has been developed by VIMS (2002, 2004). This tool reports the area of wetland loss permitted through the joint permit process by year (Figures 3.9 and 3.10). This permitting process may include USACE, USEPA, MRC, DEQ, and local wetlands boards. While this is likely not a completely accurate report of actual wetland loss, it presents relative rates of wetland loss since 1988. Possible confounding factors include permitted activities that never occur (rare), unpermitted tidal wetland losses (likely small), natural losses, and unpermitted nontidal wetland losses (difficult to ascertain) (T. A. Barnard, Jr., VIMS, pers. comm.).

Figures 3.9 and 3.10 both illustrate increasing areas over time of permitted wetland losses.

3.2.4. Statewide Aquatic Habitat Status and Trends

All aquatic species have physical and chemical habitat requirements. The natural distribution of habitats and the direct and indirect anthropogenic manipulation of them have shaped the current status of the aquatic habitats and their associated species in Virginia.

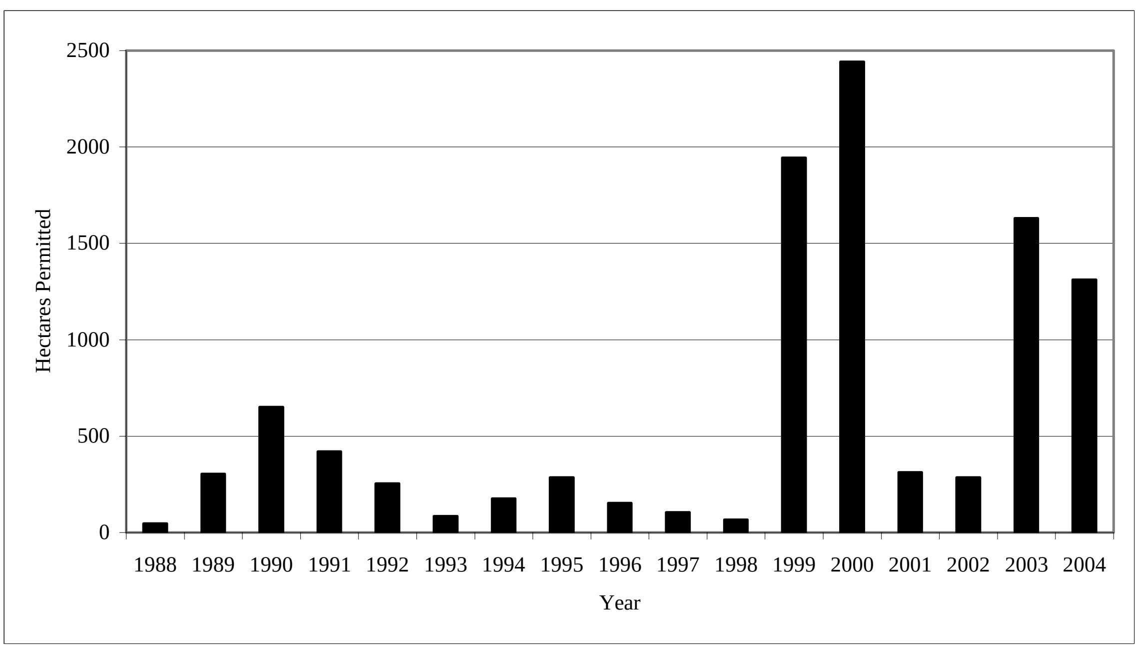

Figure 3.9. Tidal wetland permitted project areas. Hectares as reported here were converted from square feet in VIMS (2004).

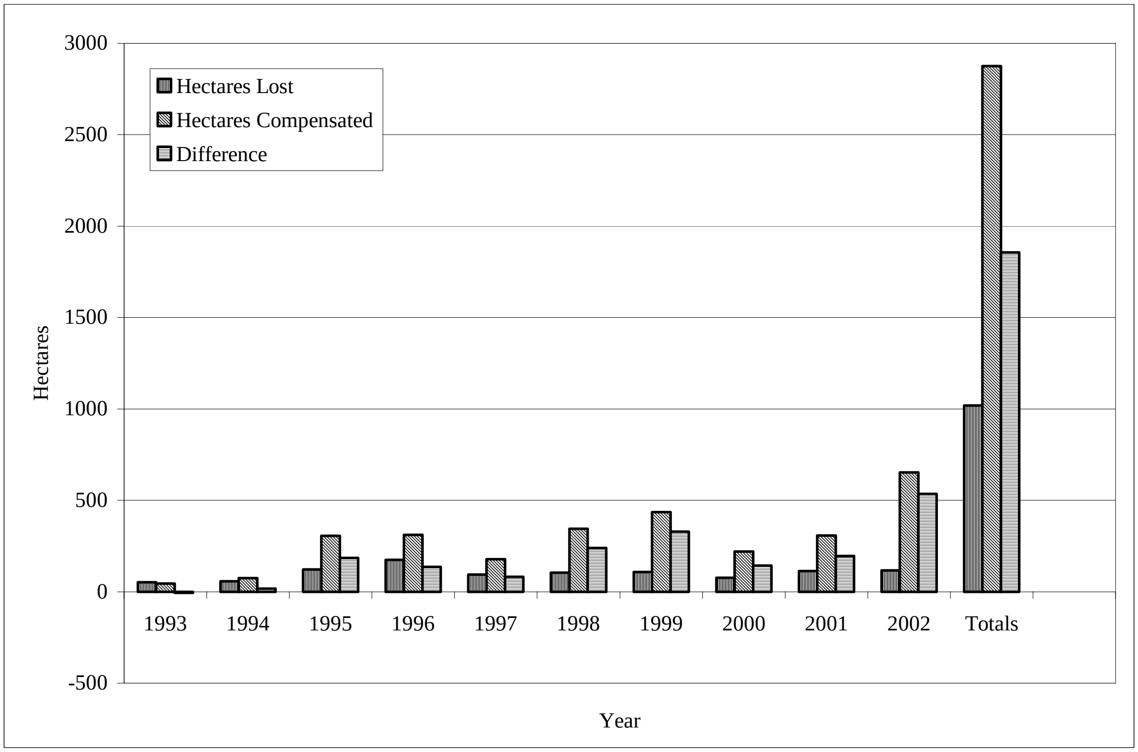

Figure 3.10. Nontidal wetland permitted project areas. "Lost" indicates the area permitted to be destroyed by projects in a given year. "Compensated" indicates the area of wetlands created, restored, or preserved as a condition of the permit. It is important to note that this figure does not necessarily indicate a net gain of wetlands, since permittees can protect other wetlands rather than restoring or creating new ones to offset damage or loss (VIMS 2002). Hectares as reported here were converted from acres in VIMS (2002).

3.2.4.1. Statewide Summary of Aquatic Habitat Classification

The DGIF aquatic habitat classification has identified 114 stream types. The Albemarle Sound-Dismal Swamp drainage and the small tributaries of the Chesapeake Bay have not been completed, but are not expected to add many (if any) new types. The classification was completed for drainages within Virginia, and includes drainage portions outside of Virginia if they were upstream of the Virginia portion. As is expected, most of the types represent headwater stream types (Table 3.6). However, the two types with the highest percentage of occurrences were very low gradient and low gradient small streams connected to other small streams. These two together comprised about 18% of the occurrences. There were 20 types that had fewer than 10 occurrences (Table 3.7). This dataset, when complete and edited, should be a valuable tool to assess, at a macro level, the diversity of stream habitats in Virginia.

Table 3.6. Distribution of stream types among size classes. These include wetland and impounded stream sections.

Size Class	Number of Types
Headwater	48
Small streams	35
Large streams	16
Small rivers	10
Large rivers	5

Table 3.7. Stream types with fewer than 10 occurrences. See Methods chapter for description of codes.

DGIF Stream Classification Type	Number of Occurrences
High gradient small stream (disconnected)	1
High gradient small stream connected to large river	1
Moderate gradient large stream connected to another large stream (impoundment or wetland)	1
Low gradient small river connected to a large river	1
Low gradient small river connected to a large river (impoundment or wetland)	1
Moderate gradient small stream (disconnected)	2
Moderate gradient large stream connected to a small river	2
Moderate gradient small stream connected to a large stream (impoundment or wetland)	3
Low gradient large stream connected to a large river (impoundment or wetland)	3
Low gradient small stream (disconnected)	4
High gradient small stream connected to a large river (impoundment or wetland)	4
Moderate gradient small river connected to another small river (impoundment or wetland)	4
Moderate gradient large river connected to another large river	4
Low large stream connected to a large river	5
High gradient headwater connected to a small river (impoundment or wetland)	6
Moderate gradient small stream connected to a small river (impoundment or wetland)	7
Very low gradient large stream connected to a large river (impoundment or wetland)	8
Low gradient large river connected to another large river	8
Moderate gradient small river connected to another small river	9
Very low gradient small river connected to a large river (impoundment or wetland)	9

3.2.4.2. Water Quality

Water quality is one aspect of the status of aquatic habitats. Numerous studies have demonstrated that temperature, pH, salinity, dissolved oxygen, turbidity, and nutrient load affect the distribution and viability of aquatic species (Thorp and Covich 1991; Rosenberg and Resh 1993; Jenkins and Burkhead 1994). The DEQ is the main entity responsible for monitoring and assessing the status of Virginia's water quality. Two of their programs or publications provided status data at the statewide level: the 303d/305b Integrated Report to the USEPA (DEQ and DCR 2004) and the Probabilistic Modeling reports (Dail et al. 2004).

305b/303d Integrated Report

The monitoring performed for this report is largely targeted monitoring. It is designed to assess regulatory compliance and local pollution (DEQ and DCR 2004). The 303d/305b report provides summaries for the state and by river basin (DEQ and DCR 2004). These summaries indicate the number of river miles, lake acres and estuarine square miles that met or did not meet standards for five different use categories: aquatic life, fish consumption, shellfish consumption, swimming, and public water supply (for explanation of these categories, see DEQ and DCR 2004). We translated these length or area measurements to percentages for each of the use categories and habitat types, for the state (Table 3.8) and for each river basin (Tables 3.9-3.17). In general, lakes and estuaries had the highest percentage of impairment. The rivers of the Chowan River-Dismal Swamp basin had the greatest percent impairment for aquatic life use. It was followed by the Potomac-Shenandoah and the Tennessee-Big Sandy river basins.

Table 3.8. Statewide summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	14.7
	Lake	46.8

Use Category	Habitat Type	Percent Impaired
	Estuary	64.4
Fish consumption	River	1.1
	Lake	52.6
	Estuary	3.0
Shellfish consumption	River	NA
	Lake	NA
	Estuary	3.8
Swimming	River	35.2
	Lake	0.9
	Estuary	4.8
Public water supply	River	0.1
	Lake	0.1
	Estuary	0

Table 3.9. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the Potomac and Shenandoah River basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	25.1
	Lake	83.7
	Estuary	14.35
Fish consumption	River	3.1
	Lake	0
	Estuary	33.1
Shellfish consumption	River	NA
	Lake	NA
	Estuary	22.0
Swimming	River	49.8
	Lake	0
	Estuary	10.1
Public water supply	River	0
	Lake	0
	Estuary	NA

Table 3.10. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the Rappahannock River basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	1.6
	Lake	0
	Estuary	71.3
Fish consumption	River	0
	Lake	0
	Estuary	18.9

Use Category	Habitat Type	Percent Impaired
Shellfish consumption	River	NA
	Lake	NA
	Estuary	8.0
Swimming	River	57.4
	Lake	NA
	Estuary	5.4
Public water supply	River	0
	Lake	0
	Estuary	NA

Table 3.11. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the York River basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	15.4
	Lake	0
	Estuary	85.9
Fish consumption	River	0.1
	Lake	29.0
	Estuary	0.3
Shellfish consumption	River	NA
	Lake	NA
	Estuary	12.7
Swimming	River	28.8
	Lake	0
	Estuary	1.4
Public water supply	River	0
	Lake	0
	Estuary	NA

Table 3.12. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the James River basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	8.1
	Lake	44.2
	Estuary	85.8
Fish consumption	River	0.1
	Lake	0
	Estuary	8.0
Shellfish consumption	River	NA
	Lake	NA
	Estuary	16.0
Swimming	River	29.4
	Lake	0

Use Category	Habitat Type	Percent Impaired
	Estuary	10.9
Public water supply	River	0.5
	Lake	0.7
	Estuary	0

Table 3.13. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the Chesapeake Bay Small Coastal basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	11.0
	Lake	5.2
	Estuary	63.8
Fish consumption	River	0
	Lake	0
	Estuary	<0.01
Shellfish consumption	River	NA
	Lake	NA
	Estuary	1.8
Swimming	River	5.7
	Lake	0
	Estuary	0.4
Public water supply	River	0
	Lake	0
	Estuary	0

Table 3.14. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the Chowan River-Dismal Swamp basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	35.1
	Lake	0.8
	Estuary	0.2
Fish consumption	River	0.1
	Lake	0
	Estuary	0
Shellfish consumption	River	NA
	Lake	NA
	Estuary	NA
Swimming	River	19.8
	Lake	0
	Estuary	0.6
Public water supply	River	0
	Lake	0
	Estuary	NA

Table 3.15. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the Roanoke River and Pee Dee basins (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	7.9
	Lake	47.8
	Estuary	NA
Fish consumption	River	1.9
	Lake	76.5
	Estuary	NA
Shellfish consumption	River	NA
	Lake	NA
	Estuary	NA
Swimming	River	64.3
	Lake	1.1
	Estuary	NA
Public water supply	River	0
	Lake	0
	Estuary	NA

Table 3.16. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the New River basin (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	6.7
	Lake	83.8
	Estuary	NA
Fish consumption	River	1.7
	Lake	6.1
	Estuary	NA
Shellfish consumption	River	NA
	Lake	NA
	Estuary	NA
Swimming	River	26.6
	Lake	0
	Estuary	NA
Public water supply	River	0
	Lake	0
	Estuary	NA

Table 3.17. Summary of the percent of assessed habitat reported as impaired (partially supporting or not supporting) for each use category in the Tennessee-Big Sandy basins (DEQ and DCR 2004).

Use Category	Habitat Type	Percent Impaired
Aquatic life	River	20.6
	Lake	95.65
	Estuary	NA

Use Category	Habitat Type	Percent Impaired
Fish consumption	River	2.4
	Lake	0
	Estuary	NA
Shellfish consumption	River	NA
	Lake	NA
	Estuary	NA
Swimming	River	42.4
	Lake	0
	Estuary	NA
Public water supply	River	0
	Lake	0
	Estuary	NA

Probabilistic Modeling

In the past, the nature of targeted monitoring efforts did not allow for a good statewide assessment of water quality ("How good is Virginia's water quality?") or an assessment of the variation in quality across state ("How does water quality vary across Virginia?") (Dail et al. 2004; DEQ and DCR 2004). The statistical validity of such summaries was always in question. In 2001, DEQ started a probabilistic modeling program (ProbMon) to address these and other concerns. It is a five-year program for non-tidal streams.

The objectives of the program are to: estimate with statistical confidence the geographic coverage and extent of aquatic conditions; provide a statistically valid snapshot of current status and a baseline for future trends analyses; develop statistical summaries and assessments of aquatic resources; and describe associations between the conditions of aquatic resources and indicators of natural and anthropogenic stressors.

To meet these objectives, a random survey design has been developed and implemented that will provide coverage of three regions (Coast, Piedmont, and Mountain). In addition, the randomization was completed such that samples were distributed approximately equally among stream sizes. The assessments include 79 chemical and physical parameters. Benthic macroinvertebrates and habitat measurements were taken at most sites, but are not reported in detail in the preliminary reports.

Dissolved oxygen is one parameter important to sustaining viable populations of aquatic species. Temperature and products from the breakdown of organic matter, including human and other animal wastes, can cause low dissolved oxygen levels, which can stress aquatic organisms. In the fall 2001 sampling window, the ProbMon program estimates that 10% of the non-tidal streams in Virginia had dissolved oxygen levels below the required standard (95% confidence interval 1-20%, DEQ and DCR 2004). However, in the spring of 2002, there were no streams below the standard minimum. Those samples with low dissolved oxygen measurements were in the Coast and Piedmont regions.

The pH of a stream is also important to maintain viable species populations. Values below 6.0 or above 9.0 are typically detrimental to aquatic organisms (Pennak 1989; Rosenberg and Resh 1993). In Virginia, most streams fall within or below this range. There are significant portions of the state influenced by acid deposition or acid mine drainage. In the fall of 2001, only 2% (±2.5%) of the state's waters were determined to have a pH below 6.0. In the spring of 2002, 18% (±16%) were found to be below this standard (DEQ and DCR 2004). The higher percentage of violations in the spring is likely due to increased precipitation and snow melt. There were no streams in Virginia found to be above the 9.0 upper limit.

Temperature affects species distributions and can affect growth, reproduction, and feeding habits. Stream temperature is influenced by air temperature, shading, elevation, and groundwater or spring inputs. During the two time periods presented in the preliminary report, no sites were found to be above the 32°C limit (DEQ and DCR 2004).

The presence of fecal coliform bacteria in a stream indicates that feces of warm-blooded animals have entered the stream. This affects the nutrient load of the stream, thus possibly affecting its ecology. This also indicates a possible increased risk of the transmission of human pathogens. In fall 2001, 9% (+/-9%) of Virginia's streams had fecal coliform levels above the allowable limit. In spring 2002, 20% (+/-15%) of Virginia's waters were found to be in violation (DEQ and DCR 2004). This seasonal difference could be due to the increased precipitation in spring, washing manure from pastures. *Escherichia coli* will replace fecal coliform in future assessments of pathogen indicators (DEQ and DCR 2004). This probabilistic modeling approach could be applied to that parameter as well.

No Virginia standards have been developed for nutrients. However, Dail et al. (2004) developed limits for phosphorus in the Piedmont and Mountain ecoregions. Based on these limits, no Mountain streams were considered poor and only 3% were considered fair, while 21% of Piedmont streams were considered fair or poor (Dail et al. 2004). There are different forms of nitrogen present in streams: nitrate, nitrite, ammonia, and total Kjeldahl nitrogen. Nitrate is the dominant form in the Mountain region, and total Kjeldahl nitrogen is dominant in the Piedmont and Coastal regions. The presence of nitrogen can indicate the presence of fertilizer, acid rain, and/or sewage effluents.

Staff of the ProbMon program sampled benthic macroinvertebrates at most sites using USEPA's Rapid Bioassessment Protocols (Barbour et al. 1999). A multimetric index, the draft stream condition index (SCI) (Tetra Tech, Inc. 2003) was applied to these samples to test its potential as an assessment tool and to further evaluate the ecoregional validity of the SCI (Dail et al. 2004). About half of the Mountain samples received "good" ratings, compared to 28% for the Piedmont.

Future and final reports from the ProbMon program should provide detailed analyses of more parameters. This will include habitat assessments to determine the amount of Virginia stream habitat that is exceptional as well as degraded. We strongly recommend the continuation of this program as an important tool to provide robust assessments of aquatic habitats and a means to provide trends data. Trends in aquatic habitat quality at the statewide, ecoregional, or stream type level are difficult to ascertain using existing data.

USGS National Water Quality Assessment Program (NAWQA)

The NAWQA program was designed to provide a means to assess the nation's water quality, to identify trends in water quality over time, and to analyze relationships between water quality and the natural features and human activities in the watershed (USGS 2005a). The application of consistent methodology will also allow for trend analyses. Currently, there are four basins in Virginia that are part of the NAWQA program: the upper Tennessee, the Potomac, the Albemarle-Pamlico, and the Delmarva Peninsula. This program began in 1991 with cycles planned at least every 10 years. While summaries of the NAWQA program are assessed at the national level, the trends based on land use should be applicable to Virginia.

At the national level, eighty percent of streams sampled in agricultural areas had phosphorus levels above USEPA goals (USGS 2005a). Perhaps surprisingly, more than 70% of the streams sampled in urban areas had phosphorus levels above the USEPA goal. In agricultural areas, pesticides were detected in 95% of samples; approximately two-thirds contained five or more pesticides. Nearly 80% of urban streams contained five or more pesticides. In fact, urban streams contained more insecticides and in higher concentrations than agricultural streams. Conversely, streams in agricultural settings have more herbicides at higher concentrations than streams in urban settings. Another finding of the NAWQA program is that pesticides that have not been used in 10 to 20 years persist in the system. In urban settings, one or more organochlorine pesticides was detected in 97% of fish collected; PCBs were detected in more than 80% of fish samples.

The Upper Tennessee River Basin:

This report summarizes assessments from 1994-1998 (Hampson et al. 2000). Fecal indicator bacteria levels were frequently higher than standards, due to both livestock influences (runoff from pastures) and deteriorating sewage systems. This was true in both surface waters and in groundwater. Herbicides were detected in 98% of all samples, but all were within drinking water standards. Insecticides were detected in fewer than 12% of all samples, and all were within drinking water standards as well. Atrazine, deethylatrazine, and tebuthiuron were the only pesticides detected more frequently than the national average. All of the reaches in this basin were below the national mean for both nitrogen and phosphorus. Volatile organic compounds were detected frequently, with trichloromethane the most commonly detected compound, but these detection frequencies were similar to national averages. In some reaches draining coal mining areas, semivolatile organic compounds (SVOCs) exceeded aquatic life guidelines. Hampson et al. (2000) also discuss the impacts of water quality in the Clinch and Powell Rivers on native freshwater mussels.

Potomac River Basin:
This report summarizes assessments from 1992-1995 (Ator et al. 1998). Nutrients and pesticides were the focus, due to the elevated concern by this area's environmental managers over these types of compounds (Ator et al. 1998). In several streams of the Potomac River Basin, elevated nutrient and pesticide concentrations were some of the highest in the nation (in the top 25% of all stream sampling sites). These high concentrations are generally related to agriculture and urbanization. Stream drainages that are intensively agricultural or urbanized also display some of the most degraded stream habitat and fish communities in NAWQA's findings. At several sites in the Potomac basin, the PCB, organochlorine, trace elements, and SVOC concentrations in streambed sediment or aquatic tissues are some of the highest levels in the country (in the top 25% of all stream sampling sites, Ator et al. 1998). The most affected streams include North Branch Potomac River, Shenandoah River, Monocacy River, and Accotink Creek (Ator et al. 1998). The drainages of these streams are intensively agricultural or urbanized. Generally, groundwater contaminants in this region, such as pesticides, nitrate, and dissolved solids, are related to agricultural use. Investigations are needed for potential urban sources of pesticides, nitrate, and volatile organic compounds (VOCs) (Ator et al. 1998).

Albemarle-Pamlico Drainage Basin (Roanoke River):
This report, which includes the Roanoke River Basin, summarizes assessments from 1992 to 1995 (Spruill et. al. 1998). Water in many streams in this basin contained relatively high concentrations of nutrients, organochlorine compounds, and trace elements in sediment, compared to NAWQA findings nationwide (Spruill et. al. 1998). Agricultural, urban, and natural sources contribute to these high concentrations. Stream habitats were relatively more degraded than those of most basins; however, fish communities were relatively less degraded than in other basins (Spruill et. al. 1998). In the Coastal Plain portion of this basin, shallow groundwater contained relatively low concentrations of nutrients, dissolved-solids, and VOCs. In agricultural zones of the outer Coastal Plain, detection frequency of herbicides was relatively high, though the concentrations were less than drinking water standards for certain herbicides (Spruill et. al. 1998).

Delmarva Peninsula:
The Delmarva Peninsula report provides findings from a 1999-2001 water-quality assessment of streams and groundwater (Denver et al. 2004). High concentrations of nitrogen, phosphorus, and pesticides reflect the prevalence of agriculture and the nature of the soil and aquifer. Water quality in streams and rivers are highly influenced by agriculture, discharge of nitrate and pesticides by groundwater, and storm runoff of phosphorus, sediment, and pesticides (Denver et al. 2004).

Because the soils and aquifer sediments of the Delmarva are rather permeable and the water table is shallow, groundwater is especially vulnerable to contamination from human activities. Nitrate and herbicide compound concentrations in the groundwater are among the highest in the NAWQA Program's findings (Denver et al. 2004). Quality of the groundwater on the Delmarva Peninsula is highly influenced by land use activities of agricultural, suburban, and urban areas and by nitrate and pesticides, which the sandy sediments and dissolved oxygen in the aquifer transport readily.

3.2.4.3. Habitat and Landscape Effects

Patterns of Land Use in Virginia and Possible Aquatic Effects

Numerous studies have been completed relating watershed land use to some measure of aquatic habitat or biological integrity. It is not clear as to the relative importance of watershed versus riparian land use (Richards et al. 1996; Wang et al. 1997; Lammert and Allan 1999). However, all relevant studies point to a lower landcover threshold for urban or developed land use (~10%) than for agricultural land use (~25-50%) (Osbourne and Wiley 1988; Wang et al. 1997): Above these thresholds, significant water quality impacts are recognized. Developed areas and associated impervious surfaces cause drastic changes to hydrologic regimes, temperature, nutrient cycling, and other aspects of aquatic systems. This is manifested in poor water quality and diminished biological communities. While agricultural land use can cause some of the same effects, the degree of change is not typically as severe or irreversible. While EDUs do not represent distinct watersheds, the percentage of developed or agricultural land use within each indicates the general trend for watersheds encompassed within an EDU (Figures 3.11 and 3.12).

The Mid-Atlantic Coastal Plain-James, Southern Appalachian Piedmont-Potomac, and Mid-Atlantic Coastal Plain-Chesapeake Bay tributaries have the highest percentages of developed land use in the state (Figure 3.11). West of the Piedmont, only the Northern Ridge and Valley-Roanoke EDU has developed land use above 5.0% (Figure 3.11).

The top category for agricultural land use includes those EDUs above 30.0%. There are eight EDU's in this category: Northern Ridge and Valley-Potomac, Southern Appalachian Piedmont-Rappahannock, Southern Appalachian Piedmont-Potomac, Mid-Atlantic Coastal Plain-Delmarva, Northern Ridge and Valley-New, Blue Ridge Mountains-New, Mid-Atlantic Coastal Plain-Albemarle, and the Mid-Atlantic Coastal Plain-Chowan (Figure 3.12).

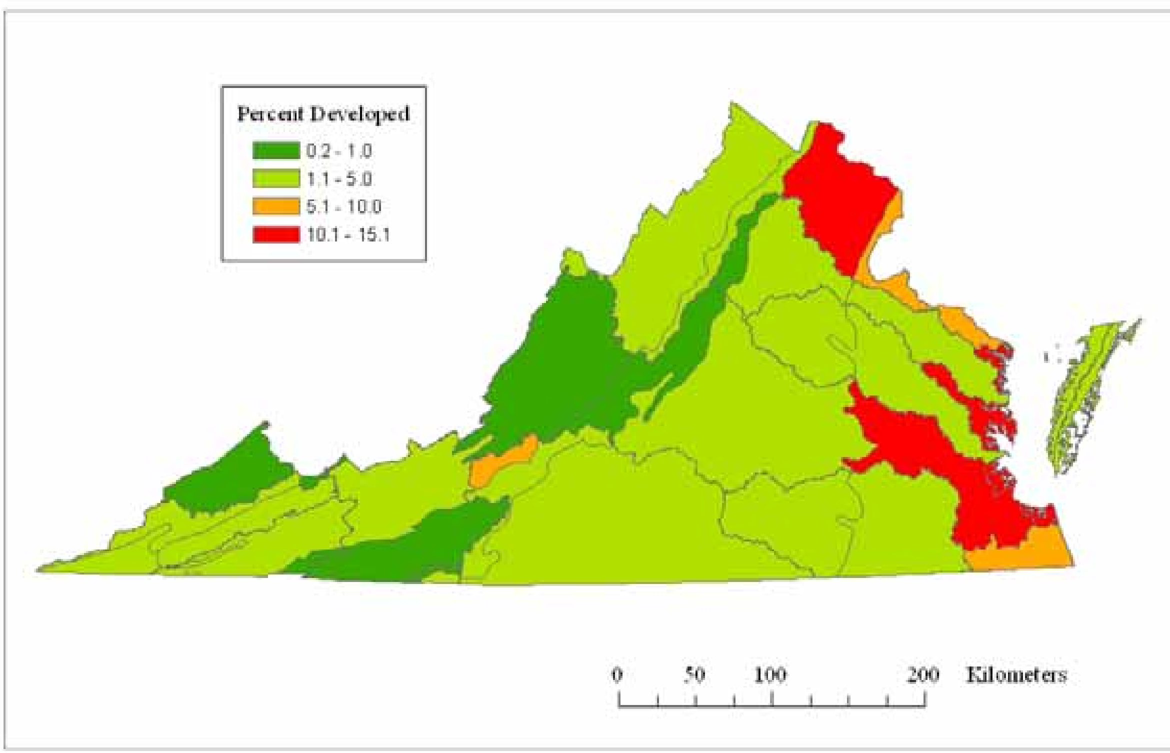

Figure 3.11. The percentage of developed land use within each EDU (USGS 1992).

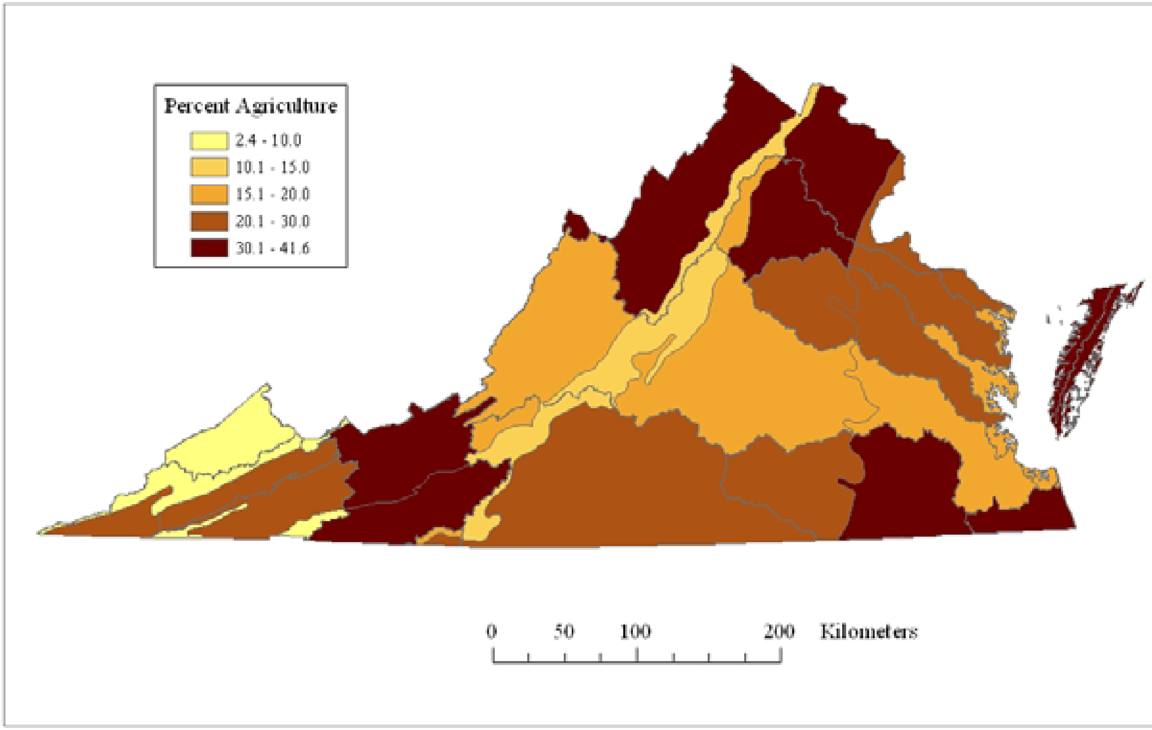

Figure 3.12. The percentage of agricultural land use within each EDU (USGS 1992).

Impediments

Impediments alter the connectivity and structure of aquatic habitats and include dams, some culverts, and waterfalls. Many dams have been breached or removed in recent years in various restoration efforts. Most recently in Virginia, the Embrey Dam on the Rappahannock River near Fredericksburg was breached. This opened up over 150km of habitat for migratory fishes such as the American shad *Alosa sapidissima*, alewife *A. pseudoharengus*, and American eel *Anguilla rostrata*, all species of greatest conservation need. This stretch of river had been blocked since 1853. In 1999, the Bosher's Dam fishway was opened on the James River. This opened approximately 220km of the James River, which is now open to Lynchburg, the supposed extent of migratory shad and herring in the James.

Despite these advances in opening habitat for migratory fishes, hundreds of smaller streams are impeded across Virginia. These impediments can block both the anadromous and catadromous runs of fishes and the daily or seasonal movements of resident freshwater fishes. These blockages can isolate populations of all aquatic organisms. For example, freshwater mussels that rely on fish to reproduce may be left without an appropriate host fish (or at least a limited means of dispersal).

Dam construction has led to the impoundment of thousands of hectares of habitat in Virginia. Impoundments destroy free flowing stream habitat and can affect hydrology, nutrient cycling, and temperature regimes above and below their footprint. In addition, impoundments typically contain different aquatic communities than stream habitats and are frequently stocked with game fish not native to the drainage in which the impoundment exists (Jenkins and Burkhead 1994). Dams were built at mill sites in Virginia as early as 1646; however, larger dams such as those for power generation were not constructed until the middle of last century (Mussey 1948).

Sedimentation

Sedimentation, or siltation, is a pervasive threat to aquatic organisms throughout the state. Jenkins and Burkhead (1994) indicated that siltation may be the "most widespread and insidious depressant of many species." They pointed to sedimentation in the Piedmont, the Big Sandy drainage, and other localized areas as the most acute. Sediment alters habitat by filling in interstitial spaces, which are important as habitat for macroinvertebrates and as spawning habitat for many fish species. Detailed information on sedimentation or erosion rates for Virginia could not be found.

Stream Channel and Stream Bed Alteration

Stream channel and bed alteration occur under a variety of circumstances including agriculture, forestry, and urban development. Streams have often been channelized to increase drainage of adjacent property, to facilitate development, or to speed movement of water. Stream beds have been altered during these processes and also to create corridors for transportation.

It is difficult to characterize and enumerate the amount of habitat that has been affected by channelization and stream bed alteration. However, a recent report summarizes the linear feet of stream impacts authorized under the DEQ Water Protection General Permits and the State Program General Permits, available through DEQ and USACE (USACE 2004). According to this report, DEQ has authorized 40,677 linear feet (12,398m) of stream impacts for residential, commercial and institutional activities from January 1, 2004 to October 31, 2004. In addition, DEQ authorized 10,746 linear feet (3,275m) of stream impacts from linear transportation projects (e.g., stream crossings). The USACE has authorized 26,206 linear feet (7,988m) of stream impacts for residential, commercial, and institutional activities from January 1, 2004 to October 31, 2004. In addition, the USACE authorized 4,846 linear feet (1,477m) of stream impacts for linear transportation projects affecting >300ft (91m) of stream bed. Some degree of mitigation or restoration was required through these permits.

It is unclear what the effects of these authorized impacts are on the aquatic resources of Virginia, nor is it clear how this level of impact compares to past years. Organizations such as DEQ, VIMS, and USACE are creating and implementing tracking tools for these data. It will be useful to be able to query specifics about the nature of specific impacts and have some sort of spatial reference tool (e.g. GIS application). While an individual project may not threaten the resource, the cumulative impact of multiple projects within a watershed (or over time) could.

3.2.5. Statewide Special Habitat Status and Trends

The habitats discussed in this section are those with limited spatial and trends data. These habitats also support many rare and specialized species, including a number of Virginia's species of greatest conservation need.

3.2.5.1. Vernal Pools

Vernal pools are generally small, shallow water bodies, in or adjacent to forests or wooded areas, that flood seasonally. These ponds typically reach maximum water levels in spring and dry up annually or every few years, but contain water at least two months in most years. They are isolated with no in-flowing or out-flowing streams—they lack continuous surface water connection to any permanently flooded water bodies. As such, they are unable to support established fish populations, but do support species that are adapted to seasonal drawdown and that reproduce successfully when fish predation is absent. These vernal pool-dependent species include the mole salamanders (family Ambystomatidae). Vernal pools are also referred to as ephemeral pools or ponds, temporary ponds, spring pools, intermittent woodland pools, seasonal forest ponds, geographically isolated wetlands, and seasonally astatic waters (Colburn 2004).

Vernal pools have high ecological value and must be protected due to their unique role in an ecosystem. They support many species that are adapted specifically to this habitat and that are unable to survive in any other. This dependence is related to temporary flooding, which provides a fish-free environment for breeding. A single vernal pool often supports an entire populations; its destruction may also destroy that

population. Clearly, if large numbers of vernal pools are destroyed, then these species may be at risk of extinction.
Vernal pools are directly threatened by filling, draining, dredging, shoreline clearing, mosquito control, pollution (including acid deposition), and introduced/invasive floral and faunal species (Petranka 1998; Colburn 2004). Activities in the watershed that indirectly affect vernal pools and directly affect some vernal pool dependent species include development, forestry, and clearing for agricultural and recreational purposes (Petranka 1998; Colburn 2004). Clearcutting forests that surround vernal pools is detrimental to vernal pool species, since many species that breed in this habitat live in the surrounding forests as adults (Petranka 1998; Hayslett 2003).

By the middle of the 19th century, approximately 85% of the northeastern United States was deforested, and these clearings were converted to fields, pastures, and wood lots. Over time, due to changes in the economy and politics, many of these agricultural lands were abandoned and forest regrowth occurred. This second growth was accompanied by a reestablishment of many forest-dependent species and their populations. However, in recent years, these second growth forests are being threatened by clearing for residential and commercial development. Due to this habitat's ephemeral nature and the inconspicuous nature of its fauna, it has often been ignored by wildlife conservation programs (Colburn 2004).

There are several approaches to vernal pool conservation. These include using existing regulations and laws to protect this habitat. For instance, the U.S. Clean Water Act has been used increasingly in recent years to protect vernal pools, since one of the goals of this Act is to protect wildlife habitat. Some state and municipal laws protect wetland and water quality as well. Further, if a vernal pool supports any species that is listed as endangered or threatened, then the pool may be protected by threatened and endangered species laws. Other approaches to vernal pool conservation may include zoning tools, closer review of development, implementation of forestry BMPs, easements and other restrictions to development, land acquisition by conservation agencies and organizations, ecological management planning and implementation, pool restoration and/or creation, or education and incentives provided to landowners and land managers (Petranka 1998).

3.2.5.2. Caves and Karst

Karst is distinctive, best known for its underground drainage systems. It is made up of landforms that are the products of rock dissolved by water. Caves and surface collapses (sinkholes) are typical features of karst (Watson et al. 1997). Virginia's caves occur primarily in the western portions of the state among carbonate (especially limestone) and other sedimentary rocks. There are a few limestone and related carbonate rocks in the eastern portion of Virginia that have caves (Douglas 1964).

Human uses of caves have included military and religious purposes, sanitoria, burial, manufacturing, water storage, dwelling sites, mushroom farming, cheese-making, wine-making and storage, smuggling, scientific research, tourism, concert auditoria, and other forms of recreation (Watson et al. 1997).

Caves and karst are vulnerable to threats due to a dependence on the integrity of the relationship between water, land, vegetation, and soils. Any change to the hydrologic system threatens the karst system. Meanwhile, any degradation of the karst will ultimately impact the hydrologic system. Caves that are left dry and static due to lowered groundwater levels are particularly vulnerable to human-use activities. Meanwhile, caves that contain an active stream or that undergo seasonal flooding are more dynamic in nature, and less likely to be impacted by human activities (Watson et al. 1997). According to Douglas (1964) and Holsinger (1975), the greatest threat to caves and cave species in Virginia is the ever-increasing number of people visiting caves, particularly during winter months when cave species are more vulnerable. Additionally, one complication to managing and protecting caves is that most caves are on private land, and many property owners are hesitant to allow managers access to these caves (Holsinger 1975).

Karst areas are threatened with destruction by such activities as mining, quarrying, bulldozing for engineering works or other development, submergence in reservoirs, and filling the habitat with waste and/or refuse (Watson et al. 1997). Irreparable alteration and damage can also occur due to forestry, clearing, quarrying, construction, agricultural activities, waste disposal, or other developmental activities.

In addition, due to their dependence on hydrology, karst systems can be irreparably damaged by pollution. Groundwater pollution rapidly transfers to karst with little or no natural filtering. This pollution can stem from dumping or discharging waste within the karst catchment area; sewage; domestic, farm, or industrial wastes; and/or gaseous hydrocarbons from fuel storages or waste sites.

Watson et al. (1997) identified several conservation strategies for caves and karst areas. These include public education; thorough environmental reviews of any impacts on karst systems; identification of total catchment areas; minimization of destructive actions by locating such activities in areas of least impact; minimization and monitoring of groundwater pollution, with monitoring taking place during storm and flood events; careful planning and monitoring of human uses; restoration of damage where possible; and careful planning of tourism, while opening no new caves to visitation.

3.2.5.3. Groundwater and Springs

Groundwater is a widely dispersed renewable natural resource. Some water seeps into the ground, eventually filling space in the soil above the bedrock. More freshwater occurs underground than in surface water (Poff 1999a); in fact, 97% of the earth's freshwater supply is groundwater. Springs are areas at the ground surface where this water is discharged. Springs range from minute seep holes, from which groundwater oozes to form wet areas on the ground, to large rock fissures or openings. Springs are usually located in lowland areas or at the bottom of a slope (Poff 1999b).

Groundwater varies throughout Virginia's physiographic provinces (Poff 1997). In the Cumberland Plateau (roughly equivalent to the Southern and Northern Cumberland Mountain ecoregions as used in this CWCS), groundwater is often sulfurous, iron-rich, and variable in quality. At depths of more than 300 feet (90m), naturally saline groundwater occurs. Some groundwater near coal mines has become too acidic for most uses. Groundwater pollution potential is moderate in this region. In the Ridge and Valley, limestone is one of the dominant rock types, along with dolomite, shale, and sandstone. The chemical composition of some of these types of rocks can affect groundwater quality, such as limestone contributing to water hardness. This province has very high potential for groundwater pollution due to the presence of features such as sinkholes and solution channels, which rapidly transport water through karst with limited filtration. In the Blue Ridge, groundwater recharge is low, since surface runoff is swift due to steep topography and thin topsoil. Groundwater quality is generally good, with the exception of some locations with high iron content. In the Piedmont, groundwater quality varies widely due to a highly diverse geology. Generally, groundwater quality is good, though a few locations have problems with acidity and high iron content. There is a moderate to low potential for groundwater pollution in this ecoregion. Finally, the Coastal Plain contains more groundwater than in any other in Virginia. Approximately half of the state's groundwater use occurs in the Coastal Plain. Domestic wells usually use the shallow water table aquifer, while municipalities and industries usually use the deeper system of artesian aquifers as their water sources. Groundwater quality is good, with the exception of a few locations that experience high levels of chloride, iron, and hydrogen sulfide. The Coastal Plain has a high potential for groundwater pollution due to porous soils and a high population density. This is particularly true for shallow aquifers.

Anything that impacts groundwater can also impact springs. Possible stresses to Virginia's springs and groundwater include improper liquid or solid waste disposal on land; impaired septic systems; petroleum spills or leaks; decomposing plant and animal material; improper pesticide or fertilizer applications; abandoned/unattended wells; saltwater intrusion; mining; or de-icing practices (Poff 1997, 1999a).

Protection measures needed for Virginia's springs and groundwater include: preservation and restoration of riparian areas; fencing streambanks from livestock; proper maintenance of septic systems; minimization of fertilizer and pesticide use; implementation of agricultural BMPs; proper disposal of wastes; utilization of best management techniques and technology in mining operations; water conservation, particularly in areas of saltwater intrusion; and proper installation, operation, maintenance, and closure of underground storage tanks (Poff 1997, 1999b).

3.3. Statewide Threats

3.3.1. Statewide Species-based Threats Assessment

The assessment of stresses on and threats to the species of greatest conservation need is critically important to effective planning, a critical middle step between species selection and determining and prioritizing effective conservation actions. This section reports the results of the TAC threats assessment meetings. We discuss three categories each for terrestrial and aquatic species: stress-source combination, which lists the top 10 unique combinations of stress and source (Tables 3.18 and 3.19); stresses independent of source, which lists all stresses reported by the TACs (Tables 3.20 and 3.21); and sources of stress independent of stress, which lists all sources of stress reported by the TACs (Tables 3.22 and 3.23). All combinations of stress and source appear in Appendix F.

The top 10 stress-source combinations for terrestrial species include some that may not be obvious (Table 3.18). The highest-ranking stress-source combination is likely the most counterintuitive: predation by native species. This may require some clarification, since native species are generally not considered the threat that municipal development or even exotic species are. Its high rank can be explained by a few different factors. One is that barrier island-nesting birds are under severe pressure from native predators, such as raccoons and larids. Since most of these barrier island birds are in Tier I or II, this is heavily weighted. In addition, populations of some Tier I species are quite low, and predation is a serious threat to them for that reason. Finally, the high rank of predation by native species is related to how threats and sources of stress were combined. For instance, predation on songbirds by native species such as raccoons and corvids increases with forest fragmentation. While the ultimate stress could be considered predation due to habitat fragmentation, it was often reported at a more proximate level as predation by native species. Both are correct; they are simply different ways of looking at one suite of stresses.

Habitat destruction and fragmentation from three sources appear in the top 10, as well as destruction due to exotic species. While destruction and fragmentation due to development are self-explanatory, these stresses due to agriculture and forestry are not necessarily intuitive. These include any aspect of agriculture and forestry. For instance, habitat destruction from agriculture may not be simply land clearing for planting, but may also include intensification of farming effort and removal of fencerows related to agricultural processes. Habitat destruction due to exotic species mostly includes competitive exclusion of native species by exotic invasive vegetation, such as *Phragmites* spp.

Road-related mortality is largely related to reptiles. Snakes and turtles are killed in large numbers on Virginia's roadways. It also includes early-successional birds, which may use habitat immediately adjacent to roadways and are thus susceptible to vehicular mortality.

Table 3.18. Top 10 stress-source combinations for terrestrial species. Numbers in the "Tier" column represent the number of species instances affected by that stress-source combination. See Section 3.5.2 for discussion of this aspect.

Stress	Source of Stress	Tier I	Tier II	Tier III	Tier IV
Predation	Native species	19	30	31	73
Habitat destruction	Municipal development	13	27	23	88
Habitat destruction	Agriculture	16	14	9	71
Predation	Exotic or introduced species	13	19	15	49
Habitat fragmentation	Agriculture	14	13	8	56
Habitat destruction	Forestry	10	21	8	48
Habitat fragmentation	Forestry	8	20	7	48
Habitat fragmentation	Municipal development	3	13	4	38
Unintentional capture/killing	Roadways	8	16	8	34
Habitat destruction	Exotic or introduced species	16	24	32	39

The top 10 stress-source combinations for aquatic species (Table 3.19) seem clearer than those for terrestrial species, but some discussion is warranted. The top stress-source combination for aquatic species is sediment load alteration due to agriculture. This can be due to many agriculture-related causes, such as erosion from fields, conversion of natural riparian vegetation, overgrazing, or denuded stream banks due to livestock. Organic pollutants from industrial rights-of-way may include leakage from pipelines or spills from railways or vehicular accidents. "Other toxin" from "industrial: other" sources includes such threats as industrial accidents, drugs and chemicals that are not removed from wastewater during treatment (such as caffeine and pharmaceuticals), and other unspecified toxins.

Table 3.19. Top 10 stress-source combinations for aquatic species. Numbers in the "Tier" column represent the number of species instances affected by that stress-source combination. See Section 3.5.2 for discussion of this aspect.

Stress	**Source of Stress**	**Tier I**	**Tier II**	**Tier III**	**Tier IV**
Sediment load alteration	Agriculture	51	53	46	134
Turbidity alteration	Agriculture	48	49	44	117
Organic pollutants	Industrial right-of-way	47	44	39	109
Change in shoreline, channel morphology, or bed structure	Agriculture	45	47	45	103
Sediment load alteration	Forestry	52	50	42	143
Other toxin	Industrial: other	69	73	67	218
Sediment load alteration	Industrial: mineral extraction	47	44	39	105
Changes to nutrient inputs	Agriculture	54	57	51	143
Change in shoreline, channel morphology, or bed structure	Municipal development	48	48	41	119
Changes to nutrient inputs	Municipal development	53	51	48	141

Stresses independent of source are somewhat less informative than the combination of the two. However, looking at the two independently does provide a broad, across-taxa view of threats.

For terrestrial species, stresses independent of source are more in line with what one might expect: the top two stresses on terrestrial species are habitat destruction and habitat fragmentation (Table 3.20). Predation, as included here, includes not only native species (as discussed above), but also exotics, which include mainly domestic cat *Felis catus* and red fox *Vulpes vulpes*, the latter on the barrier islands (where it is introduced). There are several aquatic-related stresses toward the end of the list—most of these relate to wetland species, mainly those of coastal marsh and forested wetlands.

Table 3.20. All stresses reported by TACs for terrestrial species, independent of source. Numbers in the "Tier" column represent the number of species instances affected by that stress. See Section 3.5.2 for discussion of this aspect.

Stress	**Tier I**	**Tier II**	**Tier III**	**Tier IV**
Habitat destruction	77	130	111	335
Habitat fragmentation	30	62	26	165
Predation	32	49	46	122
Habitat degradation	21	35	19	75
Insecticides	14	29	16	61
Intentional take	16	42	18	47
Natural succession	18	13	10	66
Unintentional capture/killing	69	119	63	249
Herbicides and/or fungicides	9	16	10	45
Other toxin	8	25	9	55

Stress	Tier I	Tier II	Tier III	Tier IV
Other habitat stressor	4	5	8	6
Fire suppression	14	0	6	23
Changes to nutrient inputs	11	29	30	44
Organic pollutants	2	14	8	28
Complications due to small populations	4	14	8	15
Water temperature regime alteration	3	8	5	7
Other organismal stressor	7	13	5	16
Human disturbance	6	10	4	16
Loss of ecological functions	2	4	0	18
Air temperature changes	5	12	5	22
Metals	6	20	8	39
Hydrologic regime alteration	11	19	24	31
Change in channel morphology or bed structure	3	7	3	10
Food supply or trophic structure changes	4	15	6	19
Competition	2	2	1	4
Genetic alteration (e.g., hybridization)	1	2	0	4
Salinity regime alteration	1	7	3	12
Other aquatic stressor	3	5	2	8
Turbidity alteration	0	0	0	4
Fire: manipulation of timing or frequency	1	2	0	1
Sediment load alteration	0	0	0	3
Parasitism	0	1	0	2
Changes to organic matter inputs	0	0	0	2

Stresses independent of source on aquatic species are largely what one would expect (Table 3.21). The top two, sediment load alteration and turbidity alteration, are clearly related. Habitat fragmentation in an aquatic context often refers to fragmentation due to pollution or impediments such as dams or culverts. A polluted reach can separate relatively unpolluted occupied stream segments, effectively isolated those populations. "Loss of ecological functions" is largely related to loss of the fish hosts that mussels require for reproduction. Predation in an aquatic context usually refers to predation by non-native, introduced fishes, such as flathead catfish *Pylodictis olivaris* and blue catfish *Ictalurus furcatus*.

Table 3.21. All stresses reported by TACs for aquatic species, independent of source. Numbers in the "Tier" column represent the number of species instances affected by that stress. See Section 3.5.2 for discussion of this aspect.

Stress	Tier I	Tier II	Tier III	Tier IV
Sediment load alteration	153	156	134	414
Turbidity alteration	184	177	157	439
Change in channel morphology or bed structure	141	139	125	327
Organic pollutants	97	79	81	193
Changes to nutrient inputs	108	110	99	291
Other toxin	147	146	137	392
Habitat fragmentation	96	101	78	304
Herbicides and/or fungicides	41	46	51	212
Metals	74	65	70	165
Changes to organic matter inputs	85	82	74	200
Insecticides	28	30	33	118
Hydrologic regime alteration	29	48	37	177

Stress	Tier I	Tier II	Tier III	Tier IV
Loss of ecological functions	32	23	17	17
Predation	42	37	23	65
Dissolved oxygen regime alteration	18	20	4	94
Habitat destruction	9	14	15	28
Complications due to small populations	50	45	39	102
pH regime alteration	9	11	11	51
Competition	12	17	5	64
Unintentional capture/killing	7	3	10	22
Parasitism	6	11	9	15
Intentional legal take	7	3	11	13
Other organismal stressor	5	6	5	3
Genetic alterations (e.g., hybridization)	1	2	3	6
Habitat degradation	3	1	5	1
Water temperature regime alteration	2	5	3	11
Natural succession	2	0	2	0
Air temperature changes	2	0	1	0
Food supply or trophic structure changes	3	2	7	9
Salinity regime alteration	3	1	5	6
Other habitat stressor	0	1	0	0

The top three sources of stress for terrestrial species are all related to land management: agriculture, municipal development, and forestry (Table 3.22). "Agriculture" may refer to any aspect of agricultural practices, from land clearing, to intensification, to hedgerow clearing. The relatively high ranking of native species on this list was discussed previously. "Source not appropriate" includes such stresses as complications due to small population sizes that are difficult or impossible to tie to a single source (or even multiple sources). "Unknown," near the bottom of the list, refers mostly to toxins of unknown source or organismal stresses of unknown source, such as parasitism or disease.

Table 3.22. All sources of stress reported by TACS for terrestrial species, independent of source. Numbers in the "Tier" column represent the number of species instances affected by that source. See Section 3.5.2 for discussion of this aspect.

Source	Tier I	Tier II	Tier III	Tier IV
Agriculture	68	74	58	272
Municipal development	35	88	62	219
Forestry	40	62	25	174
Native species	32	52	49	125
Exotic or introduced species	43	65	57	136
Roadways	23	64	41	106
Climate alteration or atmospheric change	14	28	18	35
Source not appropriate	16	37	30	39
Recreational use of habitat	13	25	12	31
Other land management	7	21	9	28
Atmospheric deposition	10	17	7	31
Economic use of species	6	15	6	24
Industrial: other	6	28	12	51
Industrial: power generation	9	16	5	46
Other sources of stress	1	6	3	8
Unknown	4	16	8	22

Source	Tier I	Tier II	Tier III	Tier IV
Scientific use of species	3	7	3	6
Industrial: mineral extraction	1	2	0	19
Recreational use of species	0	1	0	1
Industrial right-of-way	0	0	0	1

The top four sources of stress for aquatic species are related to management of adjacent upland sites (Table 3.23). Agriculture, municipal development, mineral extraction (largely coal mining), and forestry all contribute to sedimentation, turbidity, and toxin inputs to streams. "Source not appropriate" was used for stresses as complications due to small population sizes that are difficult or impossible to tie to a single source (or even multiple sources). "Other land management" mostly refers to landowner alterations of stream channels. "Unknown," near the halfway point of the list, refers mostly to toxins of unknown source or organismal stresses of unknown source, such as parasitism or disease.

Table 3.23. All sources of stress reported by TACS for aquatic species, independent of source. Numbers in the "Tier" column represent the number of species instances affected by that source. See Section 3.5.2 for discussion of this aspect.

Source of Stress	Tier I	Tier II	Tier III	Tier IV
Agriculture	302	322	302	908
Municipal development	237	252	231	759
Industrial: mineral extraction	210	187	184	429
Forestry	165	149	131	371
Industrial: other	130	130	129	391
Industrial: power generation	61	70	61	206
Industrial right-of-way	58	60	52	180
Source not appropriate	74	64	51	113
Other land management	50	44	43	105
Exotic or introduced species	25	33	12	128
Native species	39	36	24	20
Roadways	14	10	27	35
Unknown	45	34	34	39
Atmospheric deposition	7	4	1	27
Economic use of species	4	3	10	16
Climate alteration or atmospheric change	3	1	2	0
Recreational use of habitat	2	0	1	10
Other sources of stress	2	3	4	0
Recreational use of species	0	1	2	3
Scientific use of species	1	0	0	0

3.3.2. Conservation Issues Identified by Partners on the External Steering Committee

The CWCS External Steering Committee members worked together to identify the most critical issues that need to be addressed during the next ten years to protect wildlife and habitat in Virginia. The issues identified were (see Table 3.24 for detailed information):

- Conflicts between wildlife and humans
- Controlling invasive and exotic species
- Inadequate funding for conservation programs
- Lack of basic life history and conservation information
- Lack of public understanding and support of conservation efforts

- Land use changes resulting in habitat fragmentation
- Multiple sources of pollution
- Poor conservation ethic among the general public
- Untapped potential for coordination and outreach among conservation groups

3.3.3. Human Population and Development Trends

The conversion of natural habitat to industrial, residential, or commercial development or transportation corridors is one of the largest threats to Virginia's wildlife resources. Using human population density as a surrogate, this section presents the status and trends of development pressure.

Virginia has a population of 7,078,515 people, with an average density of 69 people per km^2 (USCB 2003). The most densely populated areas are within Fairfax County, the areas around the City of Richmond (central Virginia), and the Cities of Norfolk and Virginia Beach (the Tidewater region) (Figure 3.13, GeoLytics 2005a). Fairfax County is the most populous jurisdiction in Virginia (USCB 2003). Fairfax County, along with Arlington County, Prince William County, eastern Loudoun County, and the Cities of Alexandria, Falls Church, and Manassas make up the region known as northern Virginia, a fast-growing suburb of Washington, D.C. Mountainous western Virginia, with its most populous jurisdiction of Roanoke, and the southern Piedmont, generally have lower population densities.

Using data and software from GeoLytics, Inc., population changes from the 1980 census to that of 2000 can be compared to determine past trends (GeoLytics 2005a). There was little change within the already highly dense areas of eastern Fairfax County, City of Richmond, and the City of Norfolk (Figure 3.14). However, some of the fastest growing areas surround these urban centers, including eastern Loudoun, western Fairfax, and Prince William Counties in northern Virginia, western Henrico and western Chesterfield counties in central Virginia, and the Cities of Virginia Beach and Chesapeake in the Tidewater region. Much of Virginia's population growth (and therefore development pressure) has occurred from northern Virginia down to Richmond along the Interstate 95 corridor, then from Richmond east to Norfolk and Virginia Beach along Interstate 64. Eastern Bedford County, near the City of Lynchburg, and the area around Smith Mountain Lake are some of the relatively few higher growth areas in western Virginia. Some of the isolated high growth areas shown in Figure 3.14, such as the bright red block groups in far southwest Grayson County and central Sussex County, represent large percentage population increases, however, population density is still low.

Again using demographic data from GeoLytics, Inc., it is possible to predict population change from levels reported in the 2000 census to estimated levels in 2009. The overall population in Virginia is predicted to grow just over 11% from 2000 to 2009 (GeoLytics 2005b) (Figure 3.15). The areas shown in red are predicted to have higher adverse impact on wildlife habitat through increased human development. The trend of population growth from northern to central Virginia then southeast to the City of Chesapeake is predicted to continue. However, dramatic increases in development are estimated to occur within counties west of Interstate 95 such as Powhatan, Fluvanna, Culpepper, and Spotsylvania counties. Areas in the Cities of Suffolk, Chesapeake, and Virginia Beach, which according to VA-GAP contain the highest species richness and relatively low levels of habitat protection, are likely to be heavily affected by development.

Table 3.24. Critical issues for conservation for the next ten years, as identified by the CWCS External Steering Committee.

Inadequate Funding	**Controlling Invasive and Exotic Species**	**Lack of Public Understanding**	**Land use Changes and Habitat Fragmentation**	**Untapped Potential for Coordination and Outreach**	**Multiple Sources of Pollution**	**Poor Conservation Ethic**	**Human/ Wildlife Conflicts**	**Lack of Life History and Conservation Information**
Funding for the next 10 years Lack of sufficient funding for existing conservation programs	Invasive species Exotic species	Lack of understanding of wildlife conservation by the public Inadequate environmental education in K-12 Inadequate public education Public connection to natural resources Conservation education	Habitat loss, fragmentation, and isolation Poor land-use decision-making Integration of economic development and sound conservation Sprawl Decline of agriculture Riparian development Land conservation Inadequate land use planning Predation, due to high meso-carnivore populations	Agency coordination – federal, local, public, NGOs, state Outreach Lack of coordination among conservation entities Lack of coordination among conservation programs	Air pollution-impacts on habitat Contaminants, including mercury Light pollution Erosion and sedimentation	Personal responsibility - public demands for consumption, "want it all" syndrome Public is not involved Wasted water Lack of incentives (federal and state) to not develop	Deer over-abundance, browsing issues	Critical habitat information

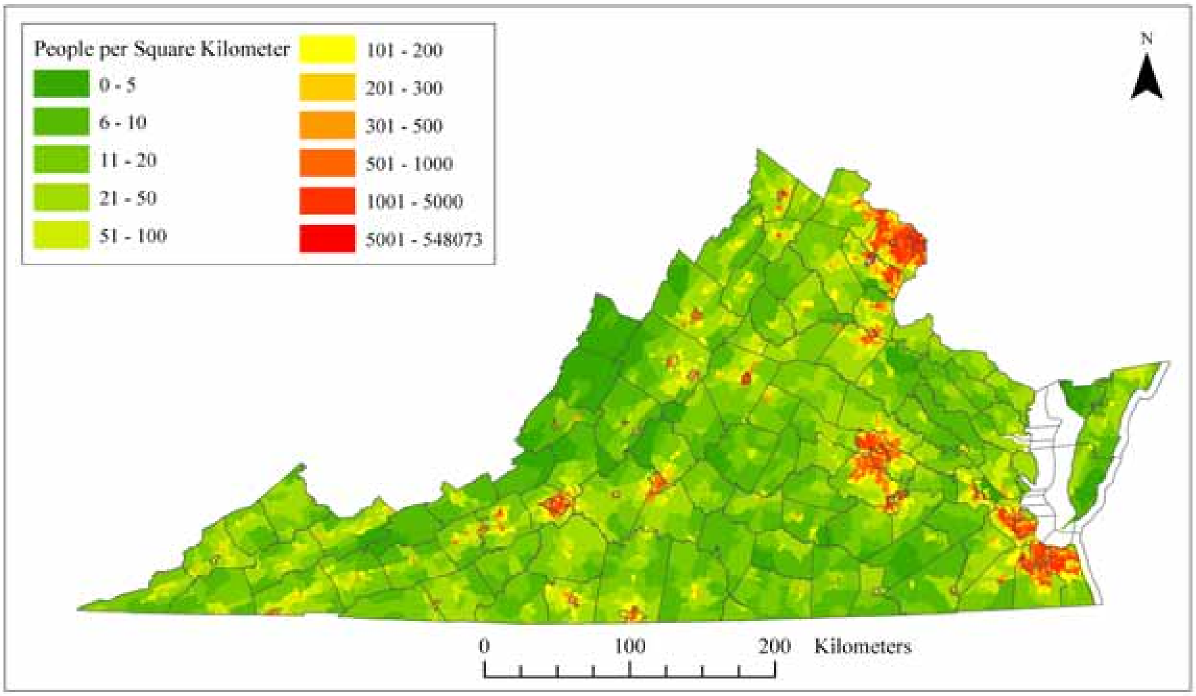

Figure 3.13. Human population density (people per km^2) from 2000 census block groups, shown with jurisdictional boundaries. This figure contains demographic data from GeoLytics, East Brunswick, New Jersey (GeoLytics 2005a).

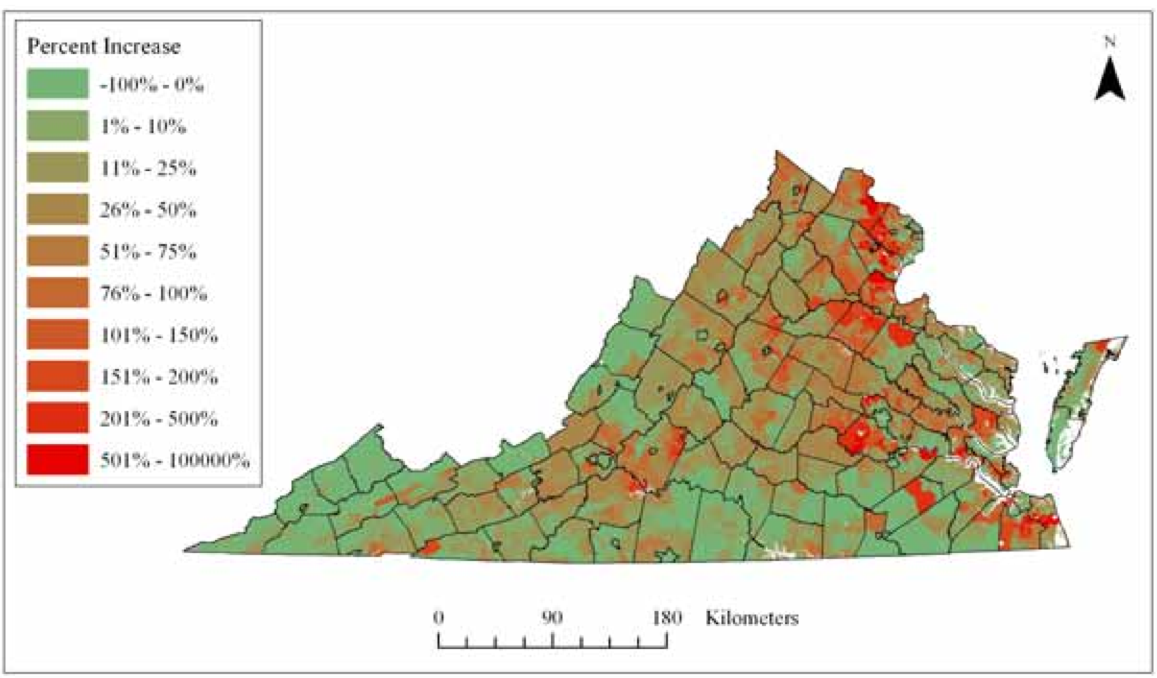

Figure 3.14. Population changes as percentages from 1980 to 2000 shown in census block groups. This figure contains demographic data from GeoLytics, East Brunswick, New Jersey (GeoLytics 2005a).

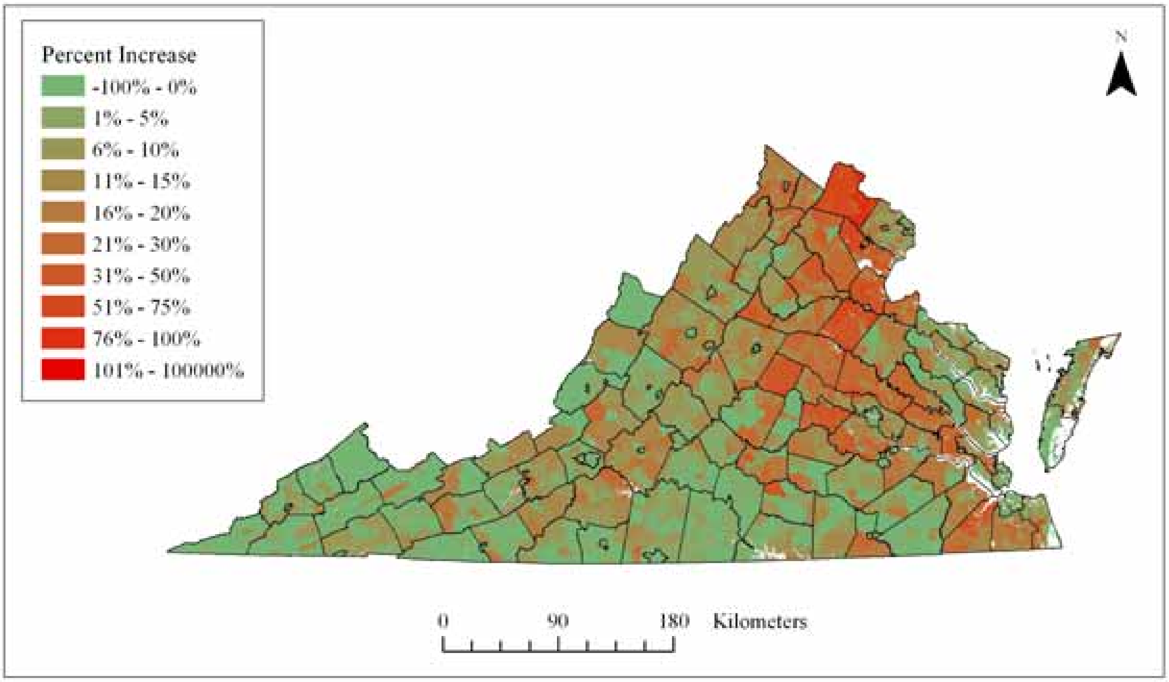

Figure 3.15. Predicted percent change in population from 2000 to 2009. This figure contains demographic data from GeoLytics, East Brunswick, New Jersey (GeoLytics 2005b).

While Figure 3.15 shows areas of predicted high growth in percentages, it does not take current population density into account. Therefore, high percentage growth could result from increases in relatively small absolute numbers of people. Areas with a combination of moderate-to-high population density in 2000 and high predicted growth are much more likely to have high-density development, and, therefore, a greater impact on wildlife resources. For example, an area with 2 people per square kilometer estimated to increase to 4 people per square kilometer exhibits 100% growth. However, this growth is expected to be less of an impact on wildlife habitat than a 100% increase in population density from 100 to 200 people per square kilometer. Figure 3.16 illustrates areas that have a 2000 population density of 20 people per square kilometer or greater, with predicted population growth of 15% or higher, over the nine year period. These are the areas that are expected to have high rates of conversion from natural habitat to human development.

Population trends vary considerably by ecoregion. Figure 3.17 shows the population density by ecoregion from 1980 to 2009. Both the Southern Appalachian Piedmont and the Middle Atlantic Coastal Plain are growing very rapidly. The Northern Ridge and Valley and Blue Ridge Mountains are growing much slower. Lastly, the Northern and Southern Cumberland Mountain regions are declining slightly (GeoLytics 2005b).

3.3.4. Potential Threat of Introduced Aquatic Species

Exotic species are a critical problem across Virginia's landscape and waterways. The vast majority of terrestrial exotics are plants, which can cause serious habitat-related issues, such as displacement of native vegetation. These particular threats are discussed in Section 3.2. The issue of exotic aquatic animals has not been discussed previously in the CWCS. The distinction between invasive vegetation and invasive animal species is important. These exotic animals often have direct organismal interactions (such as competition or predation) with native species that may be acute depressors to these native populations. Since most exotic terrestrial animals have only localized effects in Virginia (with some exceptions, such as feral cats), this section focuses on introduced aquatic animals.

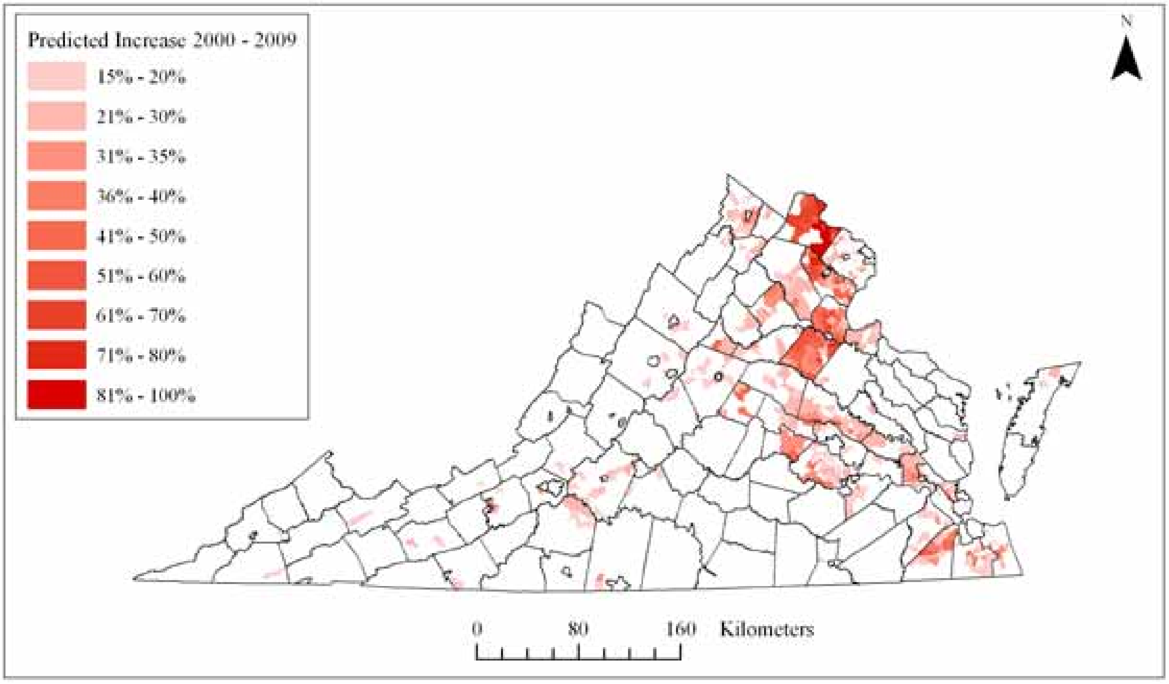

Figure 3.16. High impact growth areas. High impact growth areas consist of census block groups with 20 or greater people/km^2 in 2000 and populations predicted to grow by at least 15% between 2000 and 2009. This figure contains demographic data from GeoLytics, East Brunswick, New Jersey (GeoLytics 2005b).

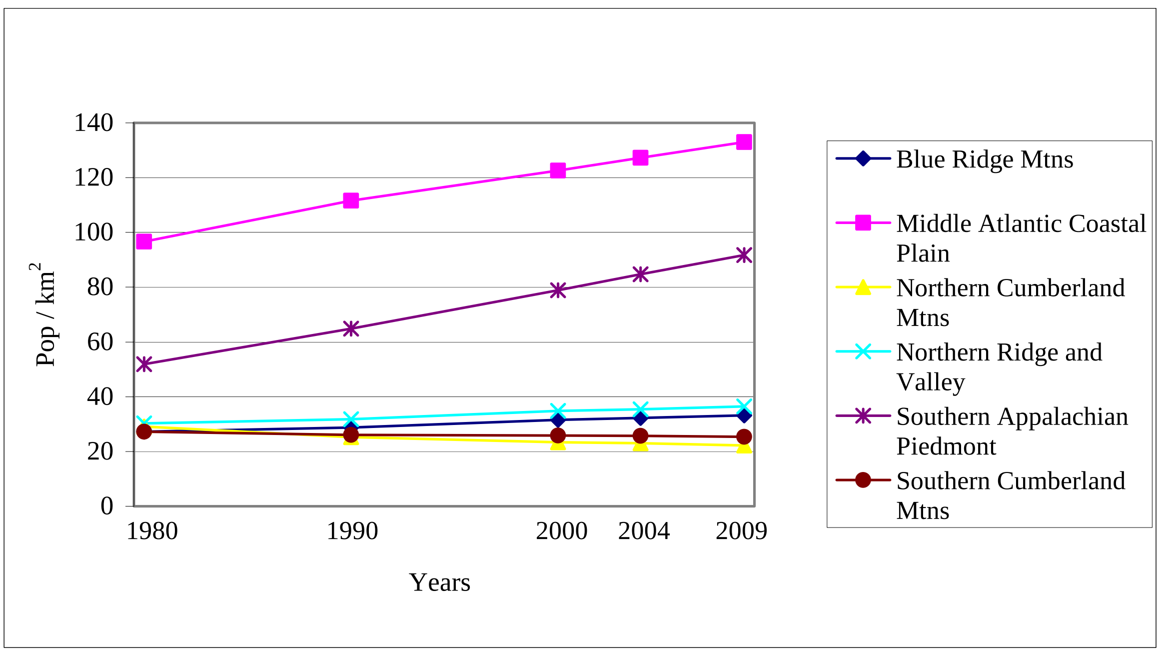

Figure 3.17. Population density trends by ecoregion. This figure contains demographic data from GeoLytics, East Brunswick, New Jersey (GeoLytics 2005).

There are a number of aquatic organisms that have been introduced to waters across the U.S. that have caused serious problems. The effects are wide ranging and include economic, biological, and ecological ramifications (ANSTF N.d.a). These introduced organisms include fish, crayfish, mollusks, and even diseases and parasites.

Many of these species have not yet become established in Virginia but have the potential to become more widespread and damaging. In 2002, the zebra mussel *Dreissena polymorpha* was found in one quarry in northern Virginia. It appears to be contained to that location, and plans are underway to eradicate the population. Where established elsewhere, the zebra mussel has drastically altered the ecology of lakes through its highly efficient filtering rate. In addition, it has negatively affected native mussel species through smothering by attaching to their shells, and it has had economic effects through the blocking of water intake structures (ANSTF N.d.c).

Another invertebrate, the rusty crayfish *Orconectes rusticus*, is native to the Ohio River basin, but may have been introduced to the Tennessee River basin in Virginia (ANSTF N.d.b). This species is spread through its use as live bait. It may escape from the hook or be dumped into the stream, lake, or pond at the end of the fishing day. This species is very aggressive and displaces native invertebrates. It can also negatively affect the local distribution of aquatic plants, which reduces habitat for invertebrates, young fish, and spawning for some species. The loss of diversity of invertebrates may reduce available food for fish, birds, and mammals.

There are several other species including the Asian clam *Corbicula fluminea*, various carp species, and others that have become established throughout much of the United States and whose effects on native wildlife are not completely understood. In addition, there are a whole host of parasites and diseases that have been unknowingly introduced to U.S. waters, including whirling disease and spring viremia of carp (Bakal 2003; ANSTF N.d.d).

However, in addition to the introduction of species from other continents, such as the zebra mussel and snakehead, there is concern about the frequent introduction of species across drainage boundaries. The impact of these introductions is unclear but certainly widespread.

Recognizing the real threat of introduced organisms, in 2003 the Virginia state legislature passed the Nonindigenous Aquatic Nuisance Species Act (Code of Virginia §29.1-571). This law only includes the snakehead fish (family Channidae), zebra mussel, and quagga mussel *Dreissena bugensis*. Among other things, this law gave DGIF the power to take action to control, eradicate, or prevent the introduction or spread of nonindigenous aquatic nuisance species.

Also in 2003, the General Assembly approved the creation of the Virginia Invasive Species Council. This council is chaired by the Secretary of Natural Resources and includes representatives from DGIF, DCR, DOF, VDOT, Virginia Department of Health, VDACS, VMRC, and VIMS. The primary purpose of this body is to coordinate State activities regarding invasive species.

The federal government has also responded to this issue with the passing of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (ANSTF N.d.a). This act created the Aquatic Nuisance Species Task Force co-chaired by USFWS and NOAA. The task force program has six focus areas: prevention, control, detection and monitoring, research, education, and technical assistance.

In the modern world, the transport of organisms across oceans and continents is happening at higher frequency and greater speed than ever before. The effects of the spread of organisms outside of their native range are only beginning to be understood, and they can be dramatic and widespread. This issue is likely to become even more of a problem without serious control and prevention programs.

3.4. Results of 2004 Community Meetings and Public Input

During the community input meetings held in 2004, DGIF received considerable feedback from participants. A total of 147 people attended the input sessions. Ninety-six different stakeholder organizations were represented covering a wide range of interests, activities and geographic boundaries (Appendix L).

A summary of each input session was prepared for review and analysis. The Hampton session contained only one participant who stayed for the opening presentation but declined to provide additional information. The following discussion reflects the comments received during the other thirteen meetings (detailed summaries of each meeting are provided in Appendix L).

3.4.1. What is Working Well and Keys to Success

Participants provided more than 200 separate examples of programs, activities and organizations that, in their opinion, are helping to conserve wildlife and habitat in Virginia. These comments were collated across all sessions and sorted into similar thematic categories. A total of ten themes emerged from these data. The themes are described below and are prioritized according to the number of sessions (in parentheses) in which a comment was provided that fell within the particular theme.

Public Education Programs (13)
Public education and outreach efforts offered through schools, local and state parks, nature camps and conservation organizations are beneficial in raising awareness of and appreciation for conservation issues. Hunter and angler education programs, *Virginia Wildlife* magazine and the *Virginia Birding and Wildlife Trail Guides* are examples of effective educational approaches.

Keys to Success
- Bringing children and adults into contact with and building their understanding of nature
- Connecting conservation efforts with economic benefits
- Increasing public interest and support for conservation efforts
- Informing future decision-makers

Habitat Protection and Restoration (13)
Local, state and national groups improve habitats and biodiversity through such efforts as dam removal, wetlands creation and improvement, or creation of freshwater impoundments. Management of existing habitats, such as National Forests and State Parks, is also important through such methods as prescribed burnings and creating connections via greenways.

Keys to Success
- Expanding cooperative efforts between the various conservation agencies and organizations
- Funding to support efforts
- Increasing biodiversity
- Replanting and growth of forests

Collaboration and Partnerships (11)
Cooperative efforts between state and federal government conservation agencies, nonprofit organizations, citizen groups and private industries to identify and protect critical habitats and species are an important contributing factor for successful conservation efforts.

Keys to Success
- Dedicated, quality staff
- Improving communication among a range of conservation groups
- Improving program effectiveness and achieving higher quality results
- Increasing the knowledge base across organizations by sharing information
- Leveraging funds and expertise

Financial Incentives (11)
State and federal programs that provide cost-sharing mechanisms for buffer strips and tax incentives for conservation easements and land donations were viewed as valuable tools for preserving habitat. Land use value taxation, Agriculture and Forest Districts, and programs to purchase development rights help keep land in fields and forest.

Keys to Success
- Cooperative, voluntary incentive programs that encourage landowners to participate
- Protecting very sensitive, fragile areas, such as stream banks
- Reducing financial pressure on landowners to develop land

Research and Knowledge (11)
Inventorying and mapping of species and habitats

Keys to Success
- Communicating and sharing information

continues to increase knowledge of resources and improves the ability to develop threat assessments. The general public and decision-makers have greater access to data and information regarding conservation needs.

- Development of management plans using improved information
- Disseminating information to the public and decision-makers
- Gathering new data and information

Conservation Organizations (10)
National, state and regional conservation organizations play an important role in identifying and protecting habitats and species. Land purchases, acquisition of easements and public education and involvement programs are examples of effective activities.

Keys to Success
- Being politically active to gain support from decision-makers
- Identifying and protecting critical habitats
- Offering ways for local people to get involved in effective conservation projects
- Passionate, dedicated staff and volunteers

Game Management (10)
Restrictions on catch and bag limits have helped restore a variety of game species and sportfish. Control of deer populations and other species helps thin herds to healthy and manageable levels and reduce conflicts between animals and humans.

Keys to Success
- Improving biodiversity
- Keeping hunters and anglers honest
- Increasing game populations

Laws and Regulations (10)
State and federal programs such as the National Environmental Policy Act, Endangered Species Act, Chesapeake Bay Preservation Act, and tidal and non-tidal wetlands regulations help to preserve critical habitat. Local watershed plans and development standards requiring buffer zones, catch basins, and other water quality protection measures are beneficial.

Keys to Success
- Limiting development near fragile riparian areas
- Mandating actions and compliance
- Protecting of small, threatened species populations
- Reducing pollutant and sedimentation loads on waterways

Public Access and Use (6)
Local and state parks, aquariums, boat ramps and fishing access sites provide public access for passive and active outdoor recreational opportunities. Actively using these natural resources helps build understanding and appreciation for their value.

Keys to Success
- Offering hands-on educational programs and opportunities
- Providing direct contact with habitats and wildlife
- Readily available resources for use

Funding to Support Programs (5)
Revenues from the sale of hunting and fishing licenses and collection of fines provides income for DGIF programs as does a portion of sales tax collected from the sale of outdoor recreation equipment. Membership fees for conservation organizations provide funding for regional and local conservation initiatives.

Keys to Success
- Providing baseline funding for conservation efforts
- Funding for land acquisition and site specific habitat improvement

3.4.2. What Needs Improvement and How to Improve It

Nearly 200 comments were provided on conservation efforts that could be improved. These comments were collated across all sessions and sorted into similar thematic categories. A total of nine themes emerged from these data. These themes are described below and are prioritized according to the number of sessions (in parentheses) in which a comment was provided that fell within the particular theme.

Coordination and Working Partnerships (12)	**Suggestions for Improvement** • Coordinate conservation plans • Coordinate work efforts between state and federal agencies and nonprofits groups • Create "one-stop shop" to assist landowners with conservation efforts and decrease response time when information or assistance is requested • Enact interagency agreements among land managers to coordinate efforts • Hire more multidisciplinary personnel • Host forums to bring agencies, organizations and interested citizens together to discuss and address issues • Increase industry partnerships • Integrate data resources • Link terrestrial and marine conservation efforts • Partner with local governments and provide technical assistance
Local and Regional Land Use Planning and Development Standards (12)	**Suggestions for Improvement** • Develop and implement riparian best management practices • Develop local tree preservation ordinances • Educate local decision-makers on best practices • Hire a natural resource planner within each Planning District Commission • Incorporate habitat and species protection into local and regional land use plans • Minimize the addition of new roadways which destroy and/or fragment habitat and encourage sprawl • Provide incentives for voluntary easements and preservation of unfragmented open space • Reduce fragmentation of habitat • Reduce sprawl and destruction of habitat through redevelopment and "smart growth" techniques
Public Education and Awareness (11)	**Suggestions for Improvement** • Conduct educational workshops for youth and adults to improve environmental understanding • Create an Education Coordinator at the state level to coordinate outreach activities • Create statewide multi-media marketing campaigns to make it "cool" to conserve and communicate the value and benefits of conservation efforts • Increase wildlife education curriculum in schools and tie to the Virginia educational Standards of Learning • Inform the public about how they can get involved in their community with land development decision-making and conservation efforts • Inform the public about the economic and health benefits of conservation • Prepare educational materials for political decision-makers • Prepare publications for the general public to increase understanding about how to protect and improve water quality, habitat and wildlife diversity • Produce a resource directory listing conservation-related agencies, programs and local contact information and distribute it to the public and post it on the Internet • Utilize outdoor recreation providers as conservation educators

Habitat Improvement (10)

Suggestions for Improvement
- Create additional freshwater wetlands
- Develop a statewide land acquisition program to join fragmented habitats and wildlife corridors
- Expand stream clean-up and restoration activities
- Improve coordination of coastal impoundments and water draw downs
- Improve management of forest hardwoods, not just softwoods, on public lands
- Improve the management of public land vegetation and grasslands to maximize benefit to wildlife
- Increase technical assistance to private landowners on methods to manage and improve wildlife habitat
- Place more emphasis on preservation of existing resources versus mitigation efforts
- Promote the use of native landscaping materials through local nurseries

Control of Invasive Species, Plants and Predators (9)

Suggestions for Improvement
- Control imports and educate the public on what to look for at nurseries and pet stores
- Create cost share programs and educational materials for landowners to reduce invasive plants
- Improve pet control programs to reduce feral dog and cat populations
- Manage game populations to reduce conflicts between animals and people
- Use *Virginia Wildlife* magazine to educate the public about invasive plants and species

Enforcement of Existing Laws and Regulations (8)

Suggestions for Improvement
- Expand regulation of pesticides that are harmful to wildlife
- Improve enforcement of local erosion and sediment control ordinances
- Increase enforcement of air, water and wetland laws
- Increase the number of Game Wardens
- Provide Wardens for all wildlife sanctuaries
- Require all hunters to buy a license
- Strengthen NEPA enforcement
- Use game check-in stations to ensure accurate game counts

Funding for Conservation (8)

Suggestions for Improvement
- Create a dedicated state level source of funding to support land acquisition programs
- Create new funding sources, such as check off boxes for voluntary contributions, on hunting and fishing license applications
- Increase funding for Chesapeake Bay programs
- Increase public lobbying efforts to increase governmental funding

Incentive Programs (8)

Suggestions for Improvement
- Expand land use tax provisions
- Increase funding for buffer strip cost share programs
- Increase tax incentives for conservations easements and land donations

Legislation (5)	Suggestions for Improvement
	• Increase controls over the use of fertilizers and pesticides • Increase protections on rivers and the Chesapeake Bay • Increase the use of environmental impact studies • Provide local governments the authority to preserve and manage natural resources • Reduce permissible water and air pollutant levels • Return National Forests to multi-use to diversify habitats • Strengthen wetland laws • Eliminate hunting with dogs

3.4.3. Critical Conservation Concerns

Session participants identified more than 100 critical issues during the thirteen sessions. These critical issues were analyzed and grouped into eight general areas of critical concern (Table 3.25):

- **Decline and Fragmentation of Habitat**
  The decline and fragmentation of habitat emerged as an area of concern in all input sessions. This issue was consistently ranked as one of the highest priority concerns across the sessions (Table 3.25). Loss of habitat due to commercial, residential and roadway development was repeatedly mentioned. Lack of land use controls and development sprawl are viewed as major contributing factors to the increased fragmentation of existing habitats and wildlife corridors.

  An increase of invasive plant and animal species is also contributing to habitat decline. A rise in unwanted predators is seen as a result of habitat fragmentation. These factors contribute to the decline of biodiversity in some areas. Some concern was expressed over the proper management of existing habitats and the ability to maximize their benefit for wildlife.

- **Pollution Increases**
  The rise in pollution levels, and that the effects are being seen at the global and national levels, was also a concern identified in all sessions (Table 3.25).

  Declining water quality and quantity was a concern that surfaced in all regions of the state. Pollutants carried by surface water runoff and excessive erosion and sedimentation were often mentioned. Declining air quality was also of major concern.

- **Inadequate Funding**
  Participants in every session indicated that a lack of funding was hampering conservation efforts (Table 3.25). In general, there is a perception that conservation is not a funding priority of the state and federal governments. Successful conservation programs, such as buffer strip programs, cannot meet demand due to inadequate funding levels.

- **Public Education and Support**
  Considerable comments were offered on the need to continue and expand public education and outreach efforts in ten of the thirteen sessions (Table 3.25). Participants expressed concern that many citizens do not understand the value of natural areas and wildlife or the long-term costs and consequences of inadequate conservation. Educating decision-makers was considered critical for generating increased funding and improving local and regional planning efforts.

- **Societal Trends**
  Concern was expressed at seven of the sessions on various societal trends that are making conservation more important and also more difficult (Table 3.25). Population growth is placing increased pressures to develop open space and forested lands. Our society is highly consumptive

of resources. An increasing percentage of Virginia's population is living in suburban and urban areas, contributing to a lack of understanding and disconnect with the natural environment.

- **Coordination of Conservation Efforts**
  The need to better coordinate the variety of conservation activities being conducted by state and federal agencies, nonprofit organizations, and other conservation groups was identified as an issue at four sessions (Table 3.25). Maximizing expertise and resources can be enhanced by improved communication and expansion of partnerships.

- **Enforcement**
  Enforcement of existing laws and regulations was mentioned during two of the sessions (Table 3.25). The ability to enforce game management and water quality protection laws were viewed as areas for improvement.

These results are broader than those identified by the TACs, but largely form a superstructure into which the TAC results fit. Another round of meetings was held in the spring of 2005 to gather input from participants regarding specific actions that would address the key issues identified below. The results of these meetings can be found in Chapter 10 and Appendix L.

Table 3.25. Matrix of most frequently-cited concerns by session and priority ranking. Column numbers reflect the rank order of importance as determined by the number of votes per issue for each session. Duplicate numbers within each session reflect tie votes. Some sessions had more than one issue that was grouped into the general headings listed on the left.

	Abingdon	**Accomack**	**Alexandria**	**Annandale**	**Harrisonburg**	**Lynchburg**	**Richmond**	**Richmond Evening**	**Roanoke**	**South Boston**	**Virginia Beach**	**Virginia Beach Evening**	**Warsaw**
Coordination		5		4							5		4
Enforcement	1											3	
Funding	5	6	2	2	2	4	3	2, 5	5	3, 5	2	3	1
Game Management		4, 8					6						
<u>Habitat Decline:</u>													
Invasives		8	4	3	3		8		5	5	5	7	6
Loss	1	1	1	4		1, 3	1	1	1		1, 3	1	1
Management		1	4				5			5			
Planning				1	3, 6		2	2	2	1		3	
<u>Pollution Increase:</u>													
Overall Decline in		6			1			3	7, 10		8	6	
Air Quality			4	7		5			9		8		6
Water Quality and Quantity	1			6		2	6	5	3	4	8		
Public Education	4	1		8	5	5	4	3			4	2	1
Societal Trends			3				8	5	3, 8	2, 5	8		8

Literature Cited

ANSTF (Aquatic Nuisance Species Task Force). N.d.a. About us. Retrieved from http://www.protectyourwaters.net/aboutus.php, May 2005.

______. N.d.b. Harmful aquatic hitchhikers: Crustaceans: Rusty crayfish. Retrieved from http://www.protectyourwaters.net/crustaceans_rusty_crayfish.php, May 2005.

______. N.d.c. Harmful aquatic hitchhikers: Mollusks: Zebra mussel. Retrieved from http://www.protectyourwaters.net/mollusks_zebra_mussel.php, May 2005.

______. N.d.d. Harmful aquatic hitchhikers: Others: Whirling Disease. Retrieved from http://www.protectyourwaters.net/others_whirling_disease.php, May 2005.

Ator, S. W., J. D. Blomquist, J. W. Brakebill, J. M. Denis, M. J. Ferrari, C. V. Miller, and H. Zappia. 1998. Water Quality in the Potomac River Basin, Maryland, Pennsylvania, Virginia, and West Virginia, and the District of Columbia, 1992-96. U.S. Geological Survey Circular 1166.

Bakal, R.S. 2003. Results of wild fish testing associated with spring viremia of carp outbreak in North Carolina and Virginia. Proceedings of the 28th Annual Eastern Fish Health Workshop; April 21-25, 2003. Retrieved May, 2005, from http://www.lsc.usgs.gov/FHB/workshope/28/45.htm.

Barbour, M. T., J. Gerrisen, B. D., Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish, Second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water, Washington D.C.

Birch, T. W., S. S. Hodge, and M. T. Thompson. 1998. Characterizing Virginia's private forest landowners and their forest lands. U.S. Department of Agriculture Forest Service Northeastern Research Station, Radnor, Pennsylvania.

CBP (Chesapeake Bay Program). 2004. Wetlands protection, restoration, and enhancement. Retrieved from http://www.chesapeakebay.net/status/status_print.cfm?sid=198&print=yes, 14 April 2005.

Colburn, E. A. 2004. Vernal pools: Natural history and conservation. McDonald & Woodward Publishing, Blacksburg, Virginia.

Dahl, T. E. 1990. Wetlands losses in the United States 1780s to 1980s. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C.

Dail, M. R., J. R. Hill, G. J. Devlin, and M. J. Scanlan. 2004. A new water quality monitoring and assessment tool for Virginia's freshwater streams. Report presented at the 2004 Virginia Water Research Symposium. Retrieved from http://www.deq.virginia.gov/probmon/pdf/VWRRC.pdf, October 2004.

DCR (VA Department of Conservation and Recreation). 2003. Conservation lands database. Richmond, Virginia. http://www.dcr.state.va.us/dnh/ conslandindex.htm.

Denver, J. M., S. W. Ator, L. M. Debrewer, M. J. Ferrari, J. R. Barbaro, T. C. Hancock, M. J. Brayton, and M. R. Nardi. 2004. Water Quality in the Delmarva Peninsula, Delaware, Maryland and Virginia, 1999-2001: Reston, VA. U.S. Geological Survey Circular 1228.

DEQ and DCR (Virginia Department of Environmental Quality and Virginia Department of Conservation and Recreation). 2004. Virginia water quality assessment: 305b/303d integrated report to Congress and the EPA Administrator for the period January 1, 1998 to December 31, 2002. Richmond.

DGIF (Virginia Department of Game and Inland Fisheries). 2004. Virginia Fish and Wildlife Information Service (VAFWIS): Biota of Virginia (BOVA) online database. http://vafwis.org/WIS/ASP/default.asp.

Douglas, H. H. 1964. Caves of Virginia. Virginia Region of the National Speleological Society, Virginia Cave Survey. Falls Church, Virginia.

GeoLytics. 2005a. CensusCD. Digital spatial and tabular data. Acquired March 2005. GeoLytics, Inc. East Brunswick, New Jersey.

______. 2005b. CensusCD estimates (2004), projections (2009), consumer expenditures and profiles. Digital spatial and tabular data. Acquired March 2005. GeoLytics, Inc. East Brunswick, New Jersey.

Hampson, P. S., M. W. Treece, Jr., G. C. Johnson, S. A. Ahlstedt, and J. F. Connell. 2000. Water quality in the upper Tennessee River basin, Tennessee, North Carolina, Virginia, and Georgia 1994-98. U.S. Geological Survey Circular 1205.

Hayslett, M. S. 2003. Natural history of the mole salamander *Ambystoma talpoideum* in Virginia. Thesis, Longwood University, Farmville, Virginia.

Hershner, C., K. Havens, L. Varnell, and T. Rudnicky. 2000. Wetlands in Virginia. Virginia Institute of Marine Science, Center for Coastal Resources Management. Special Report 00-1.

Holsinger, J. R. 1975. Descriptions of Virginia caves. Bulletin 85. Virginia Division of Mineral Resources. Charlottesville, Virginia.

Jenkins, R. E. and N. M. Burkhead. 1994. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Lammert, M. and J.D. Allan. 1999. Assessing biotic integrity of streams: effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates. Environmental Management 23(2):257-70.

Morton, D. D., V. Hanumolu, A. B. Jones, K. Q. Graham, A. Martin. 2004. Incorporationg VAGAP Results Into the Virginia Fish and Wildlife Information System: A Planning/Decision Support System. Final Report for U.S. Geological Survey Award No. 02HQAG0153. Virginia Department of Game and Inland Fisheries, Richmond, Virginia.

Mussey, O. D. 1948. Major storage reservoirs of Virginia. Bulletin 9, Virginia Conservation Commission, Division of Water Resources and Power, Richmond, Virginia.

Oak, S. W., J. R. Steinman, D. A. Starkey, and E. K. Yockey. 2004. Assessing oak decline incidence and distribution in the southern U.S. using forest inventory and analysis data. Pages 236-242 *in* M. A. Spetich, editor. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Report SRS-73. U.S. Department of Agriculture Forest Service Southern Research Station, Asheville, North Carolina.

Osbourne, L. L. and M. J. Wiley. 1988. Empirical relationships between land use/cover and stream quality in an agricultural watershed. Journal of Environmental Management 26:9-27.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States: Protozoa to Mollusca. Third edition. John Wiley and Sons, Inc., New York, New York.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institute, Washington, D.C.

Poff, J. 1997. A guide to protecting Virginia's valuable resource: Groundwater. TTR3-1997. Virginia Water Resources Research Center, Virginia Tech. Blacksburg, Virginia.

______. 1999a. A guide to Virginia's ground water. Virginia Water Resources Research Center, Virginia Tech, Blacksburg.

______, editor. 1999b. A homeowner's guide to the development, maintenance, and protections of springs as a drinking water source. Virginia Water Resources Research Center, Virginia Tech, Blacksburg.

Richards, C., L. B. Johnson, and G. E. Host. 1996. Landscape-scale influences on stream habitats. Canadian Journal of Fisheries and Aquatic Sciences 53(1):295-311.

Rosenberg, D. M. and V. H. Resh, editors. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York, New York.

Scrivani, J. and J. Pemberton. 2003. Virginia's seventh forest survey. Downloaded from http://www.dof.Virginia.gov/resinfo/index-fia.shtml, 13 April 2005.

Smith, W. B., P. D. Miles, J. S. Vissage, and S. A. Pugh. 2005. Forest resources of the United States, 2002. U.S. Department of Agriculture Forest Service North Central Research Station, St. Paul, Minnesota.

Spruill, T. B., D. A. Harned, P. M. Ruhl, J. L. Eimers, G. McMahon, K. E. Smith, D. R. Galeone, and M. D. Woodside. 1998. Water Quality in the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia, 1992-95. U.S. Geological Survey Circular 1157.

Tetra Tech, Inc. 2003. A stream condition index for Virginia non-coastal streams. Retrieved from http://www.deq.virginia.gov/watermonitoring/pdf/vastrmcon.pdf, April 2005.

Thorp, J. H. and A. P. Covich, editors. 1991. Ecology and classification of North American freshwater invertebrates. Academic, San Diego, California.

Tiner, R. W. N.d. Trends in the Chesapeake Bay watershed wetlands. http://biology.usgs.gov/s+t/SNT/noframe/ne124.htm, accessed 14 April 2005.

USACE (U.S. Army Corps of Engineers). 2004. Second annual review of the Norfolk District's State Program General Permit (SPGP-01). Norfolk District. Retrieved from http://www.nao.usace.army.mil/Regulatory/spgp_2005/second_annual_review_SPGP.pdf, April 2005

USCB (U.S. Census Bureau). 2003. Virginia: 2000 population and housing unit counts. PHC-3-48. United States Department of Commerce. Washington, D.C.

USDA (U.S. Department of Agriculture). 2000. Summary report: 1997 national resources inventory (revised December 2000). Natural Resources Conservation Service, Washington, DC, and Statistical Laboratory, Iowa State University, Ames, Iowa.

USFS (U.S. Forest Service). 2001. FIA (Forest Inventory and Analysis). Digital data downloaded from http://www.nrcs2.fs.fed.us/4801/FIADB/fiadb_dump/fiadb_dump.html 04 February 2004.

USGS (U.S. Geological Survey). 1992. National Land Cover dataset: Virginia. Land cover based on classication of Landsat Thematic Mapper (TM) at 30m resolution. Digital data version 5/27/1999, downloaded from http://seamless.usgs.gov/, December 2001.

______. 2005a. The National Water-Quality Assessment Program: informing water-resource management and protection decisions. Retrieved April 2005 from http://water.usgs.gov/nawqa/xrel.pdf.

______. 2005b. What is gap analysis. http://www.gap.uidaho.edu/about/what_ is_gap_analysis.htm. Accessed April 14, 2005.

VIMS (Virginia Institute of Marine Science). 2002. Virginia nontidal wetlands impacts data home page. Available: http://www.vims.edu/rmap/wetlands. Accessed 14 April 2005. Virginia Institute of Marine Science Wetlands Program.

______. 2004. Tidal wetlands impacts data home page. Available: http://www.vims.edu/rmap/wetlands. Accessed 14 April 2005. Virginia Institute of Marine Science Wetlands Program.

Waldon, J. L., M. Vaughan, S. D. Klopfer, J. McClafferty, D. D. Morton, G. Schairer, and N. Clark. 2001. The Virginia gap analysis project final report. Conservation Management Institute, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Wang, L., J. Lyons, and R. Gatti. 1997. Influence of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries 22(6): 6-12.

Wargo, P. M., D. R. Houston, and L. A. LaMadeleine. 1983. Forest insect and decline leaflet 165, oak decline. U.S. Department of Agriculture Forest Service.

Watson, J., E. Hamilton-Smith, D. Gillieson, and K. Kiernan, editors. 1997. Guidelines for cave and karst protection. IUCN, The World Conservation Union. Gland, Switzerland.